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Third Quarter, 1951

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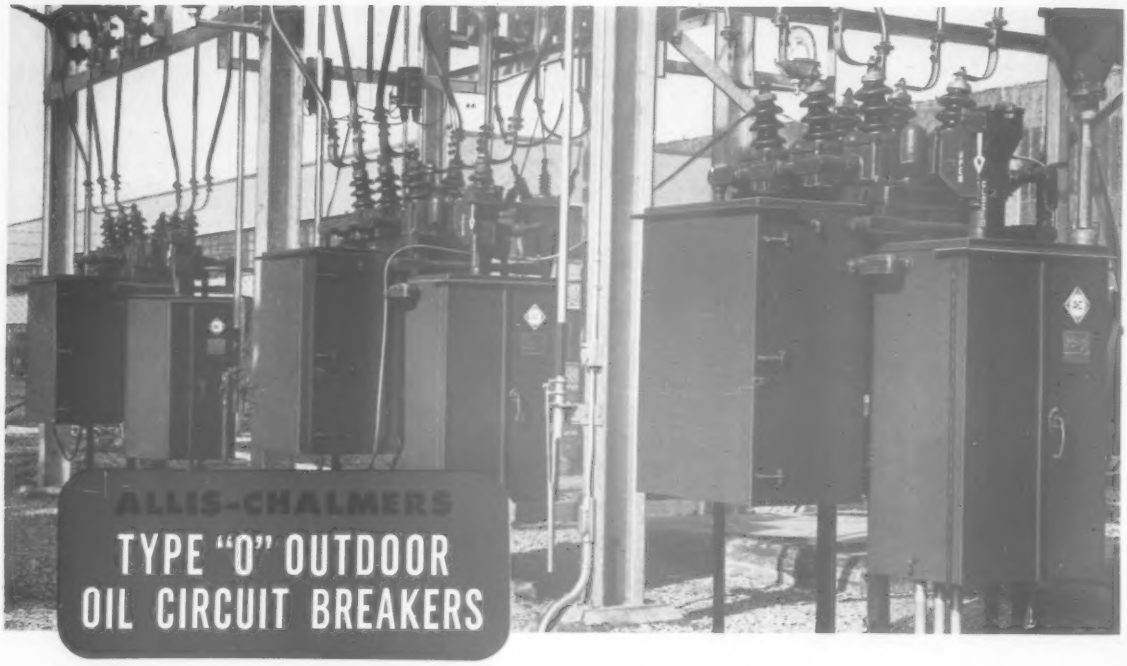

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OZ-210	14.4	1200	250,000
OZ-210	23	600	250,000

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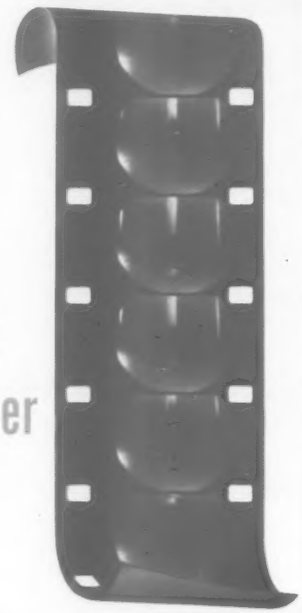

THREE-CYCLE OIL CIRCUIT breaker mechanical tests are being recorded by a high speed camera for record and analysis. Contact travel in oil was filmed through a special transparent manhole cover. Wires running along back wall of tank lead to internal floodlights.

Six consecutive frames of a typical test run filmed at 24 frames per second show a high speed opening and closing operation completed in a quarter second. Actual interruption of a short circuit would be completed during the first three inches of the 22-inch opening stroke of the contacts.

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Electrical Review

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SUPERCHARGED COOLING of

The Review is proud to present this first story of one of the truly important steps in the progress of electrical machinery design.

by STERLING BECKWITH
Engineer-in-Charge, ac Design
Motor-Generator Section
Allis-Chalmers Mfg. Co.

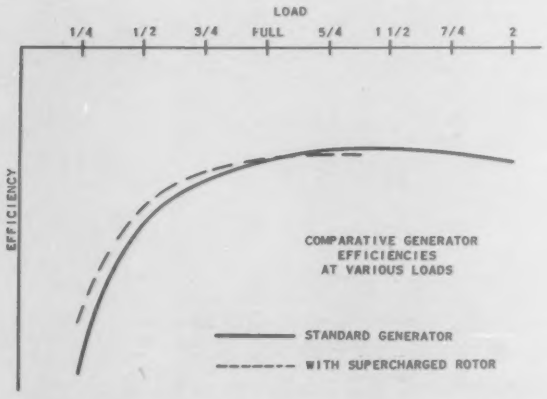
SINCE HYDROGEN COOLING was applied to synchronous generators for the first time in the early 1930's, designers have realized that only part of the full potentialities of hydrogen as a coolant have been utilized. This is because hydrogen-cooled machines have heretofore been *air-cooled* units adapted for hydrogen cooling. To fully utilize hydrogen cooling, the designer has to start from basic principles and design a *hydrogen-cooled* machine in the first place.

Development of machines to take full advantage of hydrogen cooling has been under way for several years and the first generator with a "fully hydrogen-cooled" rotor has been in service since mid-summer. This article will discuss some of the most important steps that have been taken in this very promising development.

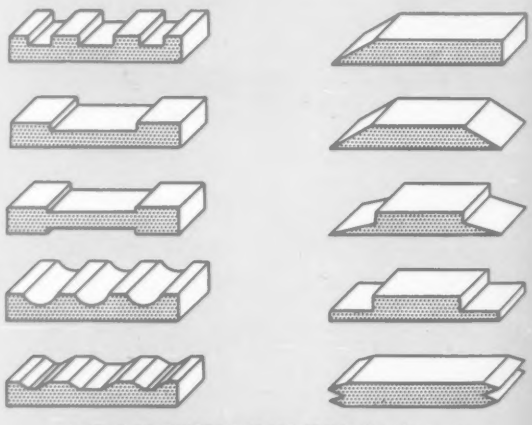
Removing rotor heat is key problem

Although it is not too well known, the rating of a two-pole turbine-driven generator, because of its inherent proportions, is determined by thermal limitations and not by efficiency or losses. The truth of this is clearly illustrated in Figure 1, in which the solid curve shows test efficiency vs. output for a typical standardized rating, 3600-rpm, hydrogen-cooled generator. Even beyond double load it can be seen that operation might be satisfactory from an efficiency standpoint, assuming the turbine would carry the load and that cooling of the machine could be done adequately.

Actually, the thermal limitations of a two-pole generator are inherently in the rotor. While it is possible to design stators which reach their thermal limits at the same time as the rotor, it is quite feasible in modern designs to increase the stator rating by deepening the stator slots. On the other hand, until now it has been thought that the rotor rating could be increased only by increasing the rotor size because stresses limit the depth to which slots can be machined.

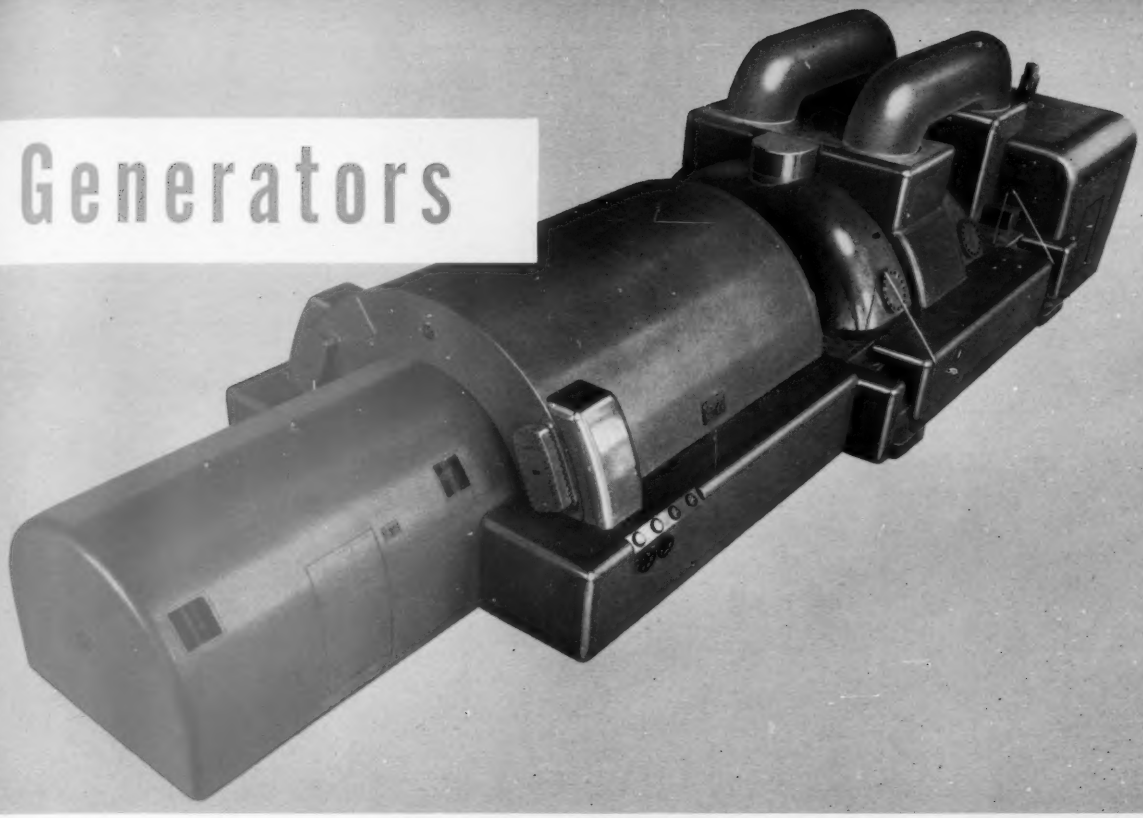


PERFORMANCE CURVES show how more efficient use of rotor copper in supercharged generator provides better fractional load efficiency and equal full load efficiency. Data for the above performance curves is based on 60,000-kw ratings. **(FIGURE 1)**



ROTOR CONDUCTOR CROSS-SECTION in the supercharged design has passageways for high speed hydrogen flow. Shown are some of the many designs studied before test coils were wound. **(FIGURE 2)**

G. of Generators



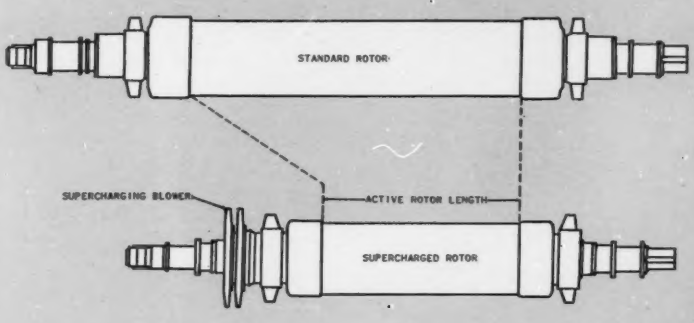
FIRST SUPERCHARGED HYDROGEN-COOLED GENERATOR was placed in service at the Wisconsin Power and Light Co. Edgewater plant in Sheboygan, Wisconsin, in June, 1951. Unit is rated 60,000 kw, 12,500 volt, 3600 rpm. Standardized design turbine uses steam at 1450 psi, 1000 degrees, with reheat. Note how supercharged design enables 60,000-kw unit to be placed in equivalent of 40,000-kw frame size.

High-pressure supercharger cools rotor

The need for a solution to this problem led to the development of a new rotor ventilating system which has been thoroughly tested and is now in service. The term best describing this new development is "supercharged cooling," as it provides a gas pressure equivalent to that obtained by supercharging. The supercharging blower, a modified centrifugal compressor, was developed on the basis of experience gained in more than 20 years of blower design. The multi-stage blower mounts directly on the shaft at one end of the rotor. This method provides a gas pressure several times that obtained with cooling fans, yet it maintains the same standards of durability and ruggedness as the remainder of the generating equipment.

With this arrangement, compressed gas can be carried to the other end of the rotor by means of a relatively small duct, and a blower at both ends of the machine is not required. Since the blower is at one end only, it can be made larger in diameter than the stator bore and will not interfere with or complicate rotor removal. The cooling gas entering the supercharger is taken from the main gas circuit of the machine at

TWO-STAGE COMPRESSOR provides several times the pressure of the usual cooling fans. Compressor was designed to same mechanical standards as the generator itself. **(FIGURE 3)**



OUTPUT PER INCH of active rotor length is 70 percent greater with supercharged cooling. Shorter bearing centers reduce balance problems, especially at higher speeds. Blower shown at left is for rotor cooling. **(FIGURE 4)**

a point just ahead of the usual stator cooling fan. After being compressed, the supercharged gas is passed through one end of two of the four main coolers, and then enters each end of the rotor. Since the amount of gas required for the rotor is small, it is actually economic to cool it to a temperature well below the 40 degrees C to which the main stator gas is cooled. However, the chief reason for cooling the rotor gas is to maintain the usual emergency rating with air instead of hydrogen.

Though the basic dimensions of the stator slots and most of the rotor structure remains unchanged, the gas-flow path through the rotor differs from standard practice. The path provides gas passages in direct contact with the rotor copper instead of vent ducts in the rotor teeth. Conductor and insulation shapes as well as the cooling network within the rotor structure have thus been changed to take advantage of the high surface speed of the cooling gas.

Much of the effort in this development was spent in evaluating the various conductor cross-sections that could be used. Some of the possible shapes considered are shown in Figure 2. A few of these have been used on other types of large machines for some time. Choice of the best cross-sections was based on cooling efficiency, heat transfer, mechanical adequacy, and adaptability to routine shop production. A detailed description of this study is, however, beyond the scope of this discussion.

Stator ventilation is identical with that which has been used on machines of standard design. The only important change in stator design is the use of somewhat more stator copper.

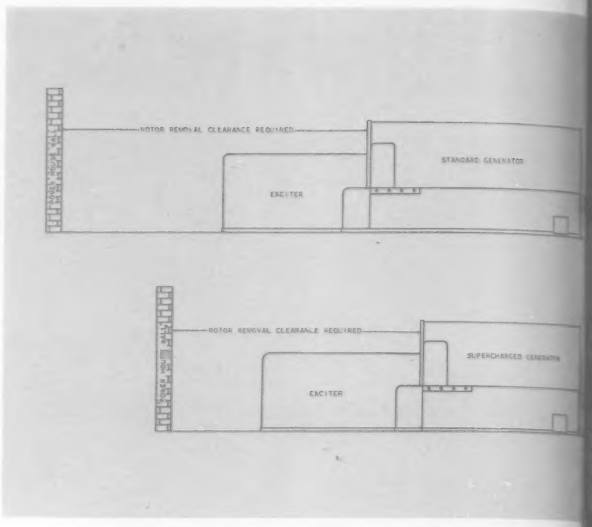
Reactance changes offer advantages

The reactance characteristics of a supercharged machine are inherently better than those of a normal machine. The higher subtransient reactance means that smaller interrupting capacity breakers may be used. It also means that short circuit torques are reduced to the point where they no longer hamper bearing and coupling design. The unsaturated synchronous reactance is substantially unaffected by the increased rating resulting from supercharging. Air gap in the new design has been increased to maintain the standard short-circuit ratio. This increase, together with the increased saturation permissible with the improved rotor cooling, gives a lower effective saturated synchronous reactance, thus providing the equivalent steady state stability of a higher short-circuit ratio machine.

Smaller powerhouses ahead

A supercharged machine cannot be identified externally except by its unusually short length. The coolers, frame, bearings, and end covers are identical in construction to those of a normal generator. When the rotor is removed, however, the supercharging blower is apparent, although the rest of the rotor appears normal. This is shown in Figure 3.

At present, the supercharged design has been applied to one frame size only. Other ratings are being developed to make use of supercharging in the near future. Since the principle is new, and since hydrogen-cooled machines must be extremely reliable and conservative in design, the first designs have not taken full advantage of the possibilities. Instead, components have been kept appreciably larger and more liberal than the design features indicated to be necessary. In spite of this, the new generator is much smaller than the best previous designs. Figure 4 illustrates the reduced space requirements in comparison with an equivalent standard machine.



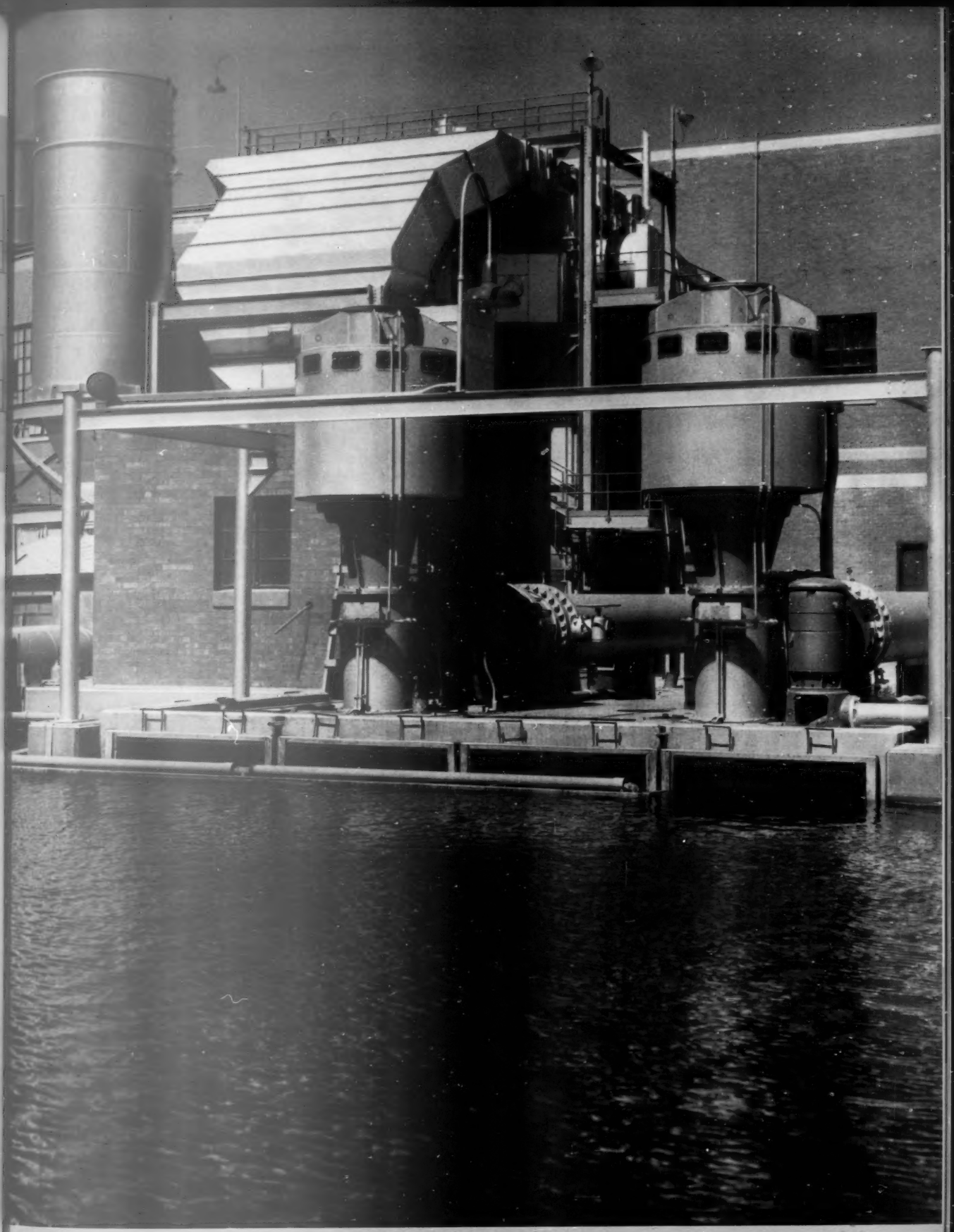
SHORTER LENGTH of the supercharged generator is shown, both units having 60,000-kw rating. The net difference in power plant width is more than nine feet with the new generator. **(FIGURE 5)**

In addition to the smaller space requirements and higher fractional load efficiency of the new generator there are numerous other advantages. These include smaller foundation and crane requirements, smaller generator bearings and hydrogen seals, greater overload rating of rotor at higher gas pressures, higher critical speed with reduced balance problems, and the ability of shipping larger machines completely assembled and tested.

Further improvements are being incorporated in supercharged machines now under construction, and the full possibilities of the principle are felt to be well beyond what has already been achieved. For example, an equal increase in hydrogen pressure gives a much greater decrease in rotor temperature on a supercharged machine than on a normal machine. Thus, a machine rated for normal operation at 15 to 25 psi hydrogen pressure with an overload rating at 30 psi and with no emergency rating in air becomes a very attractive possibility. Changes in standard methods of temperature rating are indicated in order to give total rotor rise above inlet water temperature rather than above 40-degrees C inlet gas, because of the use of different inlet gas temperatures for the rotor and for the stator.

The greater heat dissipating ability of the supercharged rotor allows a more effective use of rotor copper. Exciter size must therefore be increased somewhat to properly utilize this advantage. The losses due to this increase are only a minor factor in the overall results, being overshadowed by the reductions in other losses such as copper and bearing friction losses.

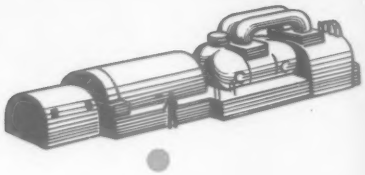
It is interesting to note that in going from air to hydrogen cooling 16 years ago, ratings of a given frame size were increased approximately 20 percent, this gain being boosted to 35 percent after several years of development. By comparison, supercharged cooling has in one step raised generator ratings 70 percent with an equivalent amount of material. Future developments may well increase this gain.



WEATHERPROOF MOTORS for condenser cooling water circulating pumps were mounted outdoors to conserve valuable building space. These tube type air-cooled squirrel cage motors are rated at 400 hp, 2300 volts, 885 rpm and drive vertical, 70-ft. head, 36 x 24-inch, 18,000-gpm pumps.

A-C Staff Photo

FIVE STAGES TO STABILITY



by **H. D. TIMM**
Engineer
and
T. B. MONTGOMERY
Engineer-in-Charge
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Allis-Chalmers Mfg. Co.

Discrepancies in generator output voltage are corrected by a series of amplifying stages in the "Regulex" regulators.

WHEN THE FIRST rotating regulators were introduced a little over a decade ago, a wide range of applications were anticipated because of their inherently high sensitivity and speed of response. Within a few years the demand for rotating regulators was even greater than could be foreseen, providing automatic control for an endless variety of jobs in industry.

Today, one of the most promising fields of application for rotating regulators is that of voltage control for generators on large power systems. The combination of accuracy, high speed of response and stability was until recently a major problem in generator voltage control development.

To solve these problems a change in concept was required. Instead of dealing with a single regulator and its control circuit, we now think in terms of an entire generation system. Within the last two years a number of these rotating regulators have gone into service and proved successful under all operating conditions. Our purpose here is to analyze a typical modern regulator system to see how component parts work together, almost to the point of "thinking ahead" to correct conditions before they arrive.

Voltage regulation for a modern generator is no longer a simple function sensitive to a single variable. Today's control must integrate the combined effect of line voltage change, reactive current division between generators, transformer drop compensation, overheating protection, system power factor, machine stability, and other factors.*

System has five stages of amplification

For the purpose of analysis we consider a typical modern regulating and generating system as a five-stage feed-back amplifier as shown in Figure 1. Since a small sample of the system output is fed back into the low energy end of the amplifying chain, the system is referred to as a closed cycle regulator. The system consists of the measuring and adjusting circuits and the five integral amplifying stages: comparator, two stage *Regulex* exciter, main exciter and the alternator. The static control components are mounted in a control cubicle as shown in Figure 2. Figure 3 shows the system in greater detail. Beginning at A we see that the voltage of the synchronous generator is reduced by standard metering type potential transformers which supply a continuous measure of generator output to be regulated.

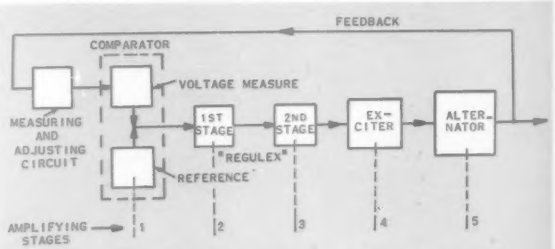
The metering voltage is connected to the voltage adjusting control (B in Figure 3) in a three-phase open delta circuit.

The voltage adjusting control consists of booster transformers connected to the adjustable taps of autotransformers in the two outside phases. The output of each booster transformer is fed differentially into its associated adjustable autotransformer to accurately set the potential transformer voltage to that required by the comparator. This circuit arrangement facilitates the use of standard variable autotransformers. The shafts of the two autotransformers are mechanically connected for adjustment of the three-phase voltage from one handwheel.

Since the comparator sets up corrective impulses based on the output of the voltage adjusting circuit, the alternator output voltage can be adjusted by changing the ratio between the potential transformer secondary voltage and the adjusting circuit output voltage. For example, to raise the alternator voltage by one percent, the taps on the autotransformer are changed so that with the same output from the measuring and adjusting circuit the potential transformer secondary voltage would become one percent higher.

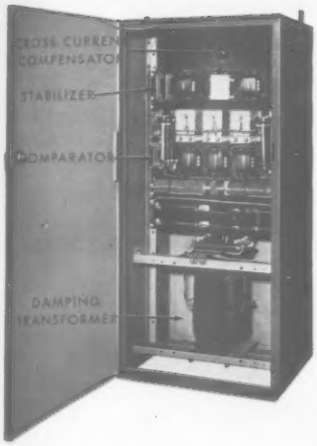
Output is continuously compared

In this as in any regulating or governing system a continuous comparison is made between the quantity regulated and a



MODERN VOLTAGE REGULATORS form closed cycle systems. A sample of the generator output is fed back into the amplifying chain to regulate the generator output voltage. **(FIGURE 1)**

* Description of these auxiliary control features will appear in a consecutive series of companion articles to be published in successive issues of the *Electrical Review*.



STATIC COMPONENTS provide high sensitivity and consistent operation under all operating conditions without contacts to break highly inductive circuits or without delicate electronic tubes. **(FIG. 2)**

standard of reference. Any deviation between these two values results in an energy signal which corrects for the deviation. A well known example is the rocking contact voltage regulator in which the force exerted by a solenoid or torque motor, energized by the voltage to be controlled, is balanced against the force of a spring. Any variation between these two opposed forces results in a corrective action. If the voltage drops due to increased load, the spring becomes stronger than the solenoid pull; regulator action increases excitation and the correct voltage is restored, re-establishing equilibrium between the two forces. The action resulting from a voltage increase is explained in a similar manner.

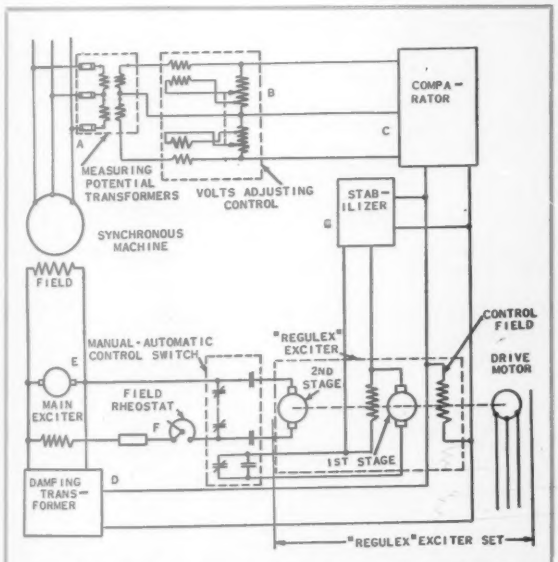
The *Regulex* voltage regulator follows the same principle. The purpose of the static voltage comparator is to continuously compare the alternator voltage with a voltage reference. The comparator also amplifies the difference between the alternator voltage and the reference voltage and supplies a corrective signal of the proper polarity and amplitude to correct the error.

These functions are accomplished by a network of static components connected in the closed cycle system at C, Figure 3. The internal connections and characteristics are shown in Figures 4 and 5. The principle of operation of the comparator can be most easily understood from the single phase connections in Figure 4a, which represents the combination of a transformer and a capacitor in a series ferroresonant circuit. Below a critical value of the applied voltage, practically no signal voltage appears across the capacitor because the capacitive impedance is small compared to the associated transformer reactive impedance.

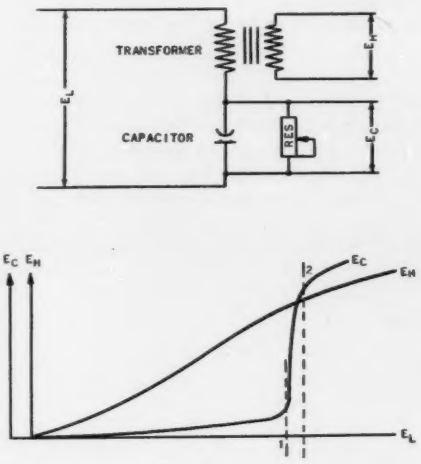
As the voltage E_L applied to this circuit is increased from zero, the transformer voltage E_H increases as shown in Figure 4b, but its increase is not proportional to line voltage increase. This characteristic is due to distortion in wave shape, partial saturation in the transformer, increase in current, and change in power factor that takes place as the critical voltage is approached.

At the same time, the increase in the applied voltage E_L from zero causes no appreciable voltage drop across the capacitive portion of this circuit until the critical voltage at the resonance line 1 is reached. The voltage E_c rises at a much faster rate than the line voltage increases at this particular point. This circuit is used to gain extreme sensitivity in producing a correcting signal of large value for a small variation in the regulated voltage.

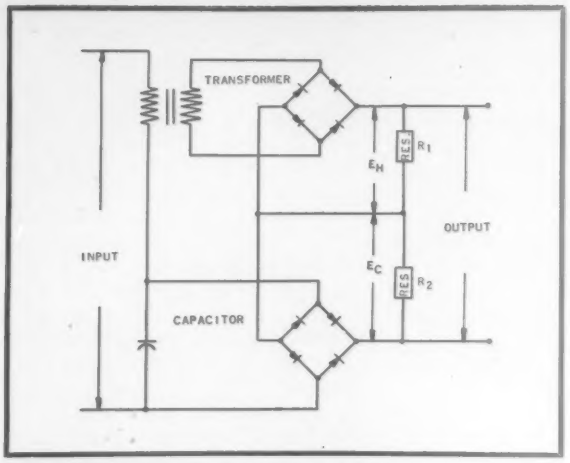
If the line voltage is increased a small amount above this critical value, the transformer voltage E_H increases only a small amount, whereas the voltage across the capacitor E_c increases suddenly to the high value as shown at line 2 and gives moderate increases at all voltages above this critical value. Thus between lines 1 and 2 a minute increase in line voltage causes a large increase in voltage across the capacitor. By suitably proportioning the transformer voltage the



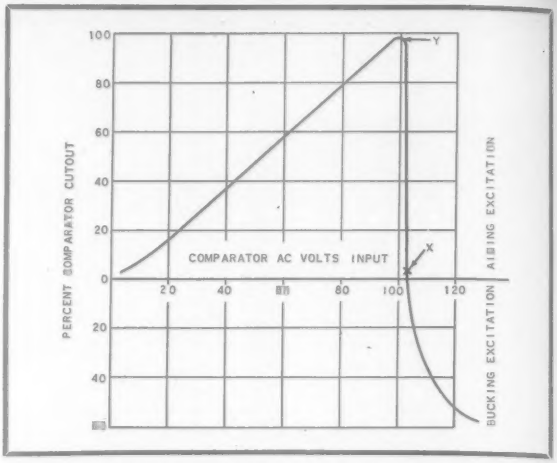
NEW CONCEPTS in voltage regulator design are reflected in their circuit arrangement. The simplified circuit shown has all the basic elements for automatic regulation of synchronous machines. **(FIG. 3)**



SERIES FERRORESONANCE obtained by a transformer-capacitor combination in the comparator triggers the regulator sending a corrective signal through the amplifying chain. **(FIGS. 4a and 4b)**



PUSH-PULL RECTIFIER output is obtained with the single-phase connection shown. The output signal of the comparator is the rectified difference between the transformer and capacitor voltages. **(FIGURE 5)**



STRONG COMPARATOR SIGNAL is the result of a slight change in ac input from the voltage adjusting circuit. When the ac voltage is high the signal bucks excitation and boosts excitation when low. **(FIGURE 6)**

output curves may be made to intersect each other as shown. This intersection is known as "crossing characteristics."

Signal is triggered

Due to the fact that the amount of saturation in iron is always the same for a given ampere turn input, the crossing of these characteristics is a convenient and accurate reference to use for initiating the triggering action of the regulator. This trigger action provides the intelligence for the controlling system.

In order to take advantage of this crossing of characteristics, the transformer reactive voltage E_H is set opposed to the capacitive voltage E_c by connections as illustrated in Figure 5. These voltages are rectified and appear across resistors R_1 and R_2 so that the output represents the difference between the two. The typical combined characteristic is shown by Figure 6.

When the comparator input voltage is at the value at which the characteristics of Figure 4b cross, there is a negligible output from the comparator. This is known as the comparator balance voltage and is shown at point X in Figure 6. When the input voltage is below the balance voltage, the comparator puts out a "boost" signal as at Y in Figure 6 to aid excitation. When the input voltage is above the balance voltage, the comparator puts out a "buck" signal to reduce excitation.

An approximation of the instantaneous voltage relationships is shown vectorially in Figures 7a, b, and c in terms of the output voltage compared to the input or line voltage. When the line voltage is low and the comparator "boosts" to Y in Figure 6, the circuit is preponderately reactive as shown in Figure 7a. These figures also show the reversal of the capacitor vector and the projections illustrate the opposition of the "buck" and "boost" circuits when the alternating currents are rectified and applied to resistors R_2 and R_1. In this case there is a resultant boost signal.

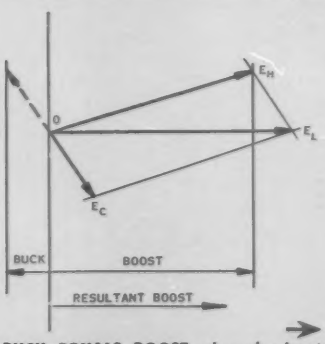
The vector in Figure 7b illustrates the condition when the comparator input or line voltage is at the balance value X in Figure 6, giving negligible output.

When the line voltage is high and the comparator reduces excitation, the vector relation is as shown in Figure 7c, and the circuit is preponderately capacitive, giving a resultant buck signal.

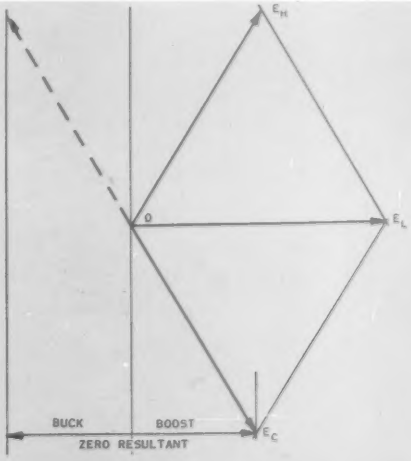
As an example, with normal load and voltage on the alternator, the adjusting circuit is set so that the comparator output is as shown at X in Figure 6. This output is amplified through the first and second stages of the *Regulex* exciter (2 and 3 respectively), in Figure 1, to supplement the self-excitation of the main exciter (4), giving the necessary excitation to the alternator (5) to produce normal voltage at its terminals. Suppose then that with sudden load application the voltage from the measuring circuit should drop two volts. The comparator output shown in Figure 6 would instantly increase from X to point Y which is 19 times the normal value. This comparator output, projected through the amplifying chain, produces a high forcing voltage across the field of the alternator to quickly bring about a change in flux in the machine and restore voltage to normal. This returns the comparator output again to point X.

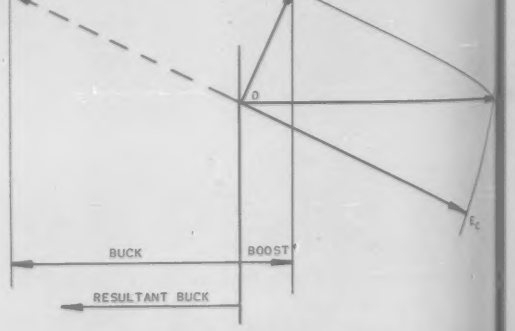
In addition to providing the reference to which the system voltage is regulated, the comparator acts as an amplifier to produce an output greater than the deviation of the measure

VOLTAGE VECTORS of the comparator show how the signal is boosted when input is lower than balance value. **(FIG. 7a)**



BUCK EQUALS BOOST when the input voltage is at balance value. Capacitor and transformer vectors are equal. **(FIG. 7b)**





RESULTANT SIGNAL bucks excitation reducing generator output when input voltage is above the balance value. **(FIGURE 7c)**

of terminal voltage from normal. However, in the normal regulating range, the output is substantially proportional to the deviation.

Similarly, when operating at point X, a reverse signal at the output terminals of the comparator will quickly reduce voltage. The amplification factor of the voltage reducing output signal is not as large as the increasing signal because system operation requires less forcing in the down direction. This reduction of forcing in the reverse direction is a convenience which allows the reverse signal to be superseded by other superimposed signals such as excitation limiting requirements.

Figure 8 shows the manner in which the control signals are generated when applied to three phase circuits as normally used. The potential transformers of most installations are provided with fuses to protect against direct short circuits. Provision is made in the comparator to limit the maximum voltage in the event of the blowing of one of the fuses.

Response time is decreased

In a high amplification feed-back system, when increased load reduces generator voltage, the comparator intelligence instigates a change to increase excitation and return the voltage to its predetermined value. The response is the opposite of the original disturbance. Generally speaking, the signals going through the system are sinusoidal and the response is 180 degrees out of time phase with the intelligence. Under these conditions, the actions are additive and hunting will result. This is illustrated in Figure 9a where A represents the intelligence signal and B represents the response. It is evident that both impulses are operating on the same sinusoidal function, one aids the other, and oscillations will be sustained.

Speeding up the response to make the signal and response less than 180 degrees apart was found to be the best way to damp oscillations and increase stability. This speed-up process is a function of the stabilizer.

In the usual inductive circuit shown by Figure 9b, the application of a constant voltage will give the exponential current rise with a time constant of S. However, with the addition of a derivative transformer in the circuit shown by Figure 9c, the transformer build-up voltage can be added to the applied voltage, the circuit time-constant can be decreased, and the circuit can be made faster in current rise. Thus, the response can be made more nearly in time phase with the signal.

In the *Regulex* regulator stabilizer, primaries of derivative transformers with small time constants are energized from the first stage *Regulex* exciter armature. These transformers are part of the stabilizer at G in Figure 3. The output impulse is returned across the first stage field. This impulse adds to the strength of the signal from the comparator and serves to compensate for the time delay inherent in the second stage field.

Since all time delays around the closed cycle system are additive, compensation for these delays results in overall stability. The actual requirements depend on the size and, therefore, the time-constant of the alternator and other components in the chain. When required, additional stability is provided by a damping transformer, D in Figure 3. Its primary is connected across a portion of the main exciter armature voltage with resistance taps to change its time constant and its secondary is also connected to the *Regulex* exciter input.

The combination of these two devices provide means for adjustments to give the correct system stability.

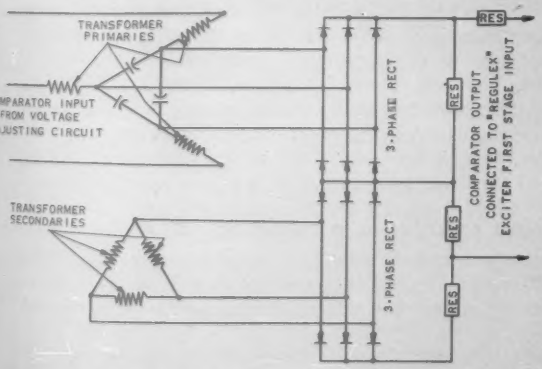
Stages differ

There is a difference in field structures between a conventional exciter and a *Regulex* exciter. The entire magnetic structure of the *Regulex* exciter is fully laminated from low-loss electrical sheet steel to reduce the hysteresis loop to a minimum. The *Regulex* exciter used on voltage regulators, as shown in Figure 10, is built as a six-pole machine to reduce the length of flux path to provide optimum response.

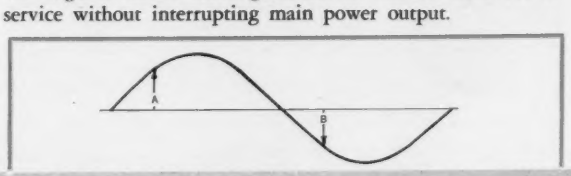
The field poles of the first stage of the *Regulex* exciter have reduced cross-sectional areas which saturate at low-field input values. This feature determines the exciter ceiling voltage and thus assures overall stability of the system by preventing extreme uncontrolled forcing. The *Regulex* exciter second stage is designed with an unusually large cross-sectional flux path to give a long portion of straight-line operation without saturation.

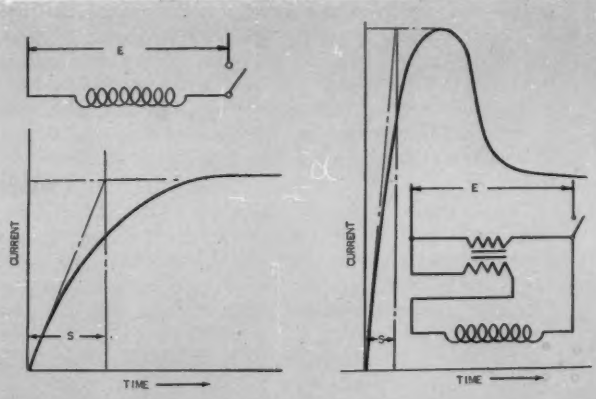
The *Regulex* exciter characteristic curve is shown in Figure 11. The broken line shows a typical amplification trace between the two stages and represents an overall voltage gain of 57 to 1. The power amplification of this machine when operating on the straight portion of the saturation curve is tremendous. Under normal forcing conditions, when the maximum required output of 240 volts is being delivered, a first stage input of 0.16 watts will give a second stage output of 1560 watts or a power amplification factor of 97,500 to 1.

On standard voltage regulators the *Regulex* exciter is usually provided as part of a separate motor-generator set as shown in Figure 12. With this arrangement the conventional pilot exciter is omitted. With self-excitation on the main exciter, the *Regulex* exciter motor-generator set can be taken out of service without interrupting main power output.



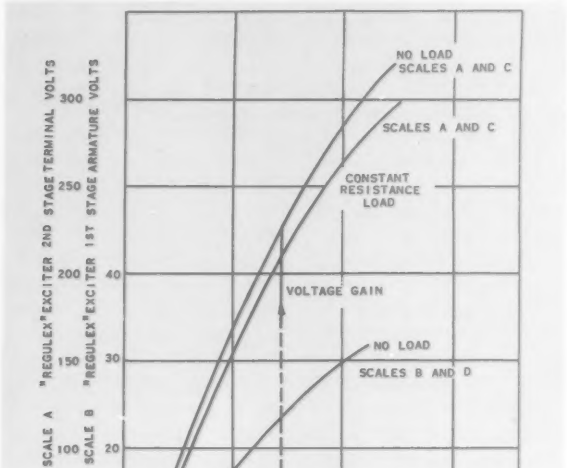
THREE-PHASE INPUT to the comparator is supplied by the voltage adjusting circuit. This connection uses three-phase rectifiers to supply the *Regulex* control field. **(FIGURE 8)**





DERIVATIVE TRANSFORMER reduces the phase angle between the intelligence and the regulator response to less than 180 degrees for system stability. **(FIGURES 9a, 9b, and 9c)**

REGULEX EXCITER shown on assembly line has two sets of laminated field structures in a single frame and two separate armatures on one shaft. Wide, sealed, prelubricated bearings extend service life. **(FIGURE 10)**



HIGH VOLTAGE GAIN makes the *Regulex* exciter especially adaptable for voltage regulator applications where field forcing is required to obtain a quick restoration of generator voltage after a disturbance. **(FIGURE 11)**

Last stages are power amplifiers

In this combination of amplifying elements where a fraction of a watt controls thousands of kilowatts, the first power amplifier of large physical size and output is the main exciter. Reference to Figure 3 will show that the field of this machine is connected across its armature for self-excitation, and that the armature of the *Regulex* exciter second state is connected in series with the self-excited field E in Figure 3 and the field rheostat F.

This scheme of connections provides maximum reliability and continuity of service, since the generator voltage may be controlled manually with the field rheostat without the automatic control in the circuit. The *Regulex* exciter, usually a part of a separately mounted motor-generator set, is driven from the station bus and has sufficient inertia to maintain full-load excitation on the main exciter through a system voltage dip of 1 to 1½ seconds. This time is longer than the duration of faults encountered in normal service on power systems and is longer than the tripping time on circuit breakers which clear such faults. Even in case the station bus voltage failed and the *Regulex* exciter should stop rotating, the main exciter remains self-excited and service continues.

The operating characteristics of a 350-volt, 350-kw stabilized exciter are shown by the voltage and field current curves of Figure 13. The high ceiling voltage for rapidly forcing a flux change in the alternator and the gradual sloping of the saturation curve on its straight line portion for stability under self-excitation with both automatic and manual control is typical of these modern machines.

Under manual operation, movement of the exciter field rheostat shifts the exciter field resistance line from OA to OB. When operating automatically the field rheostat is set at OC which results in zero output from the *Regulex* exciter under the normal full-load condition. The zero output is obtained because with the value of resistance in the field circuit giving the field line OC this characteristic intersects the saturation curve at the full-load point. At this point the total excitation of the main exciter is supplied from its own armature terminals and consequently no excitation is required from the amplifying chain. Actually, in practice some small excitation is normally supplied from the comparator as shown by X in Figure 6. An output of 240 volts from the *Regulex* exciter is available to add or subtract sufficient excitation for maximum forcing.

It will be noted that only one-half ampere from the *Regulex* exciter will move the main exciter voltage from full-load to no-load or vice versa under the usual operating conditions. This factor adds materially to the amplification and increases the overall speed of response.

The resultant field line under forcing conditions is indicated by DE in Figure 13a for raising excitation and by FG for lowering excitation. Thus, reversed exciter voltage is used to quickly reduce flux in the alternator as needed. Therefore, in a transfer from automatic to manual operation, the last action of the regulator might leave the main exciter residual in the reverse direction. To prevent accidental reversal of the exciter, provision is made to insert a small amount of battery excitation, Z in Figure 13a and 13b, so that the exciter voltage will build up in the same direction under any condition. This small battery excitation is also desirable on installations where the exciter is not stabilized. In this case the resistance line origin is shifted to point o′ shown by Figure 13b giving increased stability because of the more obtuse intersections between the resistance lines and the saturation curve.

The fifth stage and largest machine in the amplifying chain is the alternator itself. Its field is directly connected to the main exciter. From the standpoint of voltage control, the alternator is also an amplifier and, with relatively small control power from the exciter, it produces thousands of kilowatts. Designers have contributed much by means of high speed, forced ventilation, hydrogen cooling, and other factors to make these machines sensitive to the control of present day high speed regulating systems.

System operates as a continuous chain

Typical system characteristics taken from data on a 40,000-kva generator and its regulator are shown in Figure 14. In this case, 100 percent load was applied suddenly. The momentary

REGULEX SET with its static control unit (left) regulates 107,000-kw steam turbine generator. The *Regulex* exciter is rated 5 kw at 1750 rpm while its driving motor is rated 10 hp. **(FIGURE 12)**

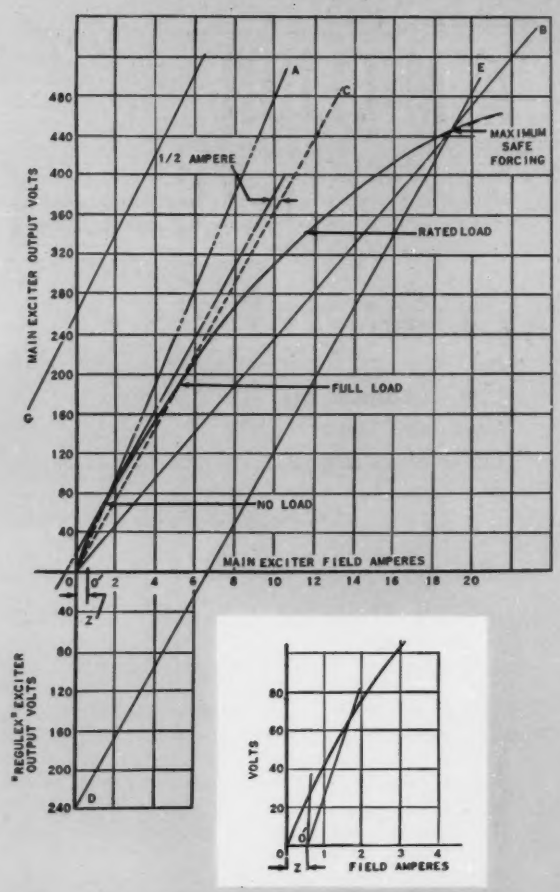
dip in generator voltage at A caused by application of load is instantly sensed by the comparator which sends an amplified signal through the amplifier chain. The voltage dip of the generator is limited primarily by the transient conditions of the machine. The instantaneous increase in field current shown at B tends to sustain the generator voltage. This increase is occasioned by the inductive coupling between the generator field and armature acting as a transformer. This inherent condition in the machine augments the action of the regulator in making corrections in excitation during system transient conditions. Before this generator field transient subsides, the control signal from the comparator causes the *Regulex* exciter to increase the output of the main exciter sufficiently to sustain the level of current produced by the transient. Further, *Regulex* exciter forcing causes increased generator field excitation until the generator voltage returns to its regulated value at vertical line 1-1.

Following the conditions represented at this line, the comparator output returns to normal, *Regulex* exciter voltage is reduced, and the main exciter sustains its own voltage at the required value shown at C. This value of excitation maintains the regulated generator voltage with the added load. The damping and stabilizing circuit minimizes the overshoot by speeding up response and bringing the system to balance at the new value of excitation.

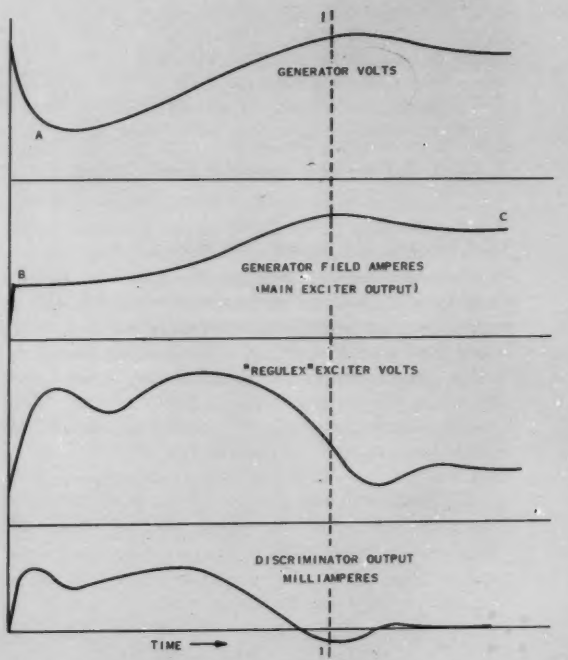
Before the advent of rotary regulators, operating engineers of some large power utilities were reluctant to use any type of automatic voltage regulator. They relied entirely on manual control. This attitude was occasioned by the lack of confidence in devices with contacts to make or break highly inductive circuits. Since the need for contacts in rotating voltage regulators has been eliminated by the use of static control components, rotary regulators have been generally accepted for controlling even the largest generators on power systems.

In the process of obtaining an extremely sensitive voltage regulator that is stable under all operating conditions, the development of the *Regulex* exciter has been supplemented by developments in magnetic amplifiers and ferro-resonant circuits. These static elements have provided high sensitivity, stability, and consistent operation without the inherent limitations of electronic circuits such as tube filament life, fragile construction, and output change with aging.

The combination of static amplifying elements and rotary amplifiers integrated into a regulating chain has provided sensitivity considered impossible a few years ago and has set new standards for the future.



NORMAL MAIN EXCITER self excitation is adjusted for generator full load. Adding or subtracting a small amount to this self-excitation causes a large change in total excitation. **(FIGURES 13a and 13b)**



SUDDENLY APPLIED LOAD invariably causes a generator voltage dip. Rotary regulators return the voltage to a steady state at the regulated value faster than any other known methods. **(FIGURE 14)**

A MILLION *Breaks*

by **A. H. BAGUHN**
and
G. W. LENGNICK
Transformer Section
Allis-Chalmers Mfg. Co.

Contacts require special materials and design to assure long, efficient service.

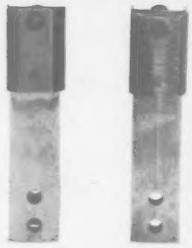
DEVELOPING LOAD-INTERRUPTING CONTACTS that provide long, trouble-free operation is one of the basic problems arising from the increased application in recent years of tap changing under load equipment in power transformers, regulators, and unit substations. Since the number of operations per day required in this type of equipment is far greater than that which is customary in circuit breaker applications, the design problems encountered are somewhat different.

In circuit breaker contact design, the principal objective is to provide a contact that will interrupt loads of the order of thousands of kva. In tap changer mechanisms, the goal is to maintain extremely long contact life. Consequently, contact materials chosen to fill the need must have the highest possible resistance to burning due to arcing and, at the same time, must possess adequately high conductivity to prevent overheating. After the best possible materials have been chosen, there is still the problem of using such materials to their best advantage; that is, to provide a contact which undergoes the least damage to the current-carrying surface when interrupting an arc.

Service determines material and design

In order to determine whether or not a material is suitable, a life test of many thousands of operations must be run. Figure 1 shows a movable contact before and after such a life test. Although considerable mass remains on the burned contact, it has almost outlived its usefulness, since there is little current-carrying surface remaining. Further use would result in complete loss of contact surface. This problem cannot be completely eliminated, because electrical erosion must accompany the arcing which occurs on circuit interruption. However, a thorough analysis of the service conditions, electrical and mechanical factors, and temperature rise will assist the selection of the best contact material as well as the design of the contact itself. Each of these service conditions determines certain properties required of the contact material.

Electrical factors which influence contact design and selection of materials for tap changing under load contacts are transition voltage and load current.



MOVABLE FINGER CONTACT before and after interruption life test shows need for analysis of factors to select the best contact material. **(FIGURE 1)**

Mechanical factors to be considered are frequency of operation, practicable contact pressure, wear due to friction, and impact of the contacts. These are important since the contacts perform over 300 operations per day in many instances.

Temperature rise of current-carrying parts depends upon the magnitude of current, type of material, the mass of the contact and its backing material, heat dissipating surface, and contact pressure.

Analysis of these factors indicates that the following properties are desirable and necessary in the ideal contact material:

1. High electrical and thermal conductivity.
2. High thermal capacity.
3. Low contact resistance.
4. Resistance to electrical erosion.
5. Resistance to sticking or welding.
6. Resistance to mechanical wear and impact.

There is no contact material which has all of these properties to the greatest extent. Some materials have high resistance to wear and arc erosion, but have high electrical resistance. Others have good thermal and electrical conductivity, but have little resistance to arc erosion.

Pro's and con's of accepted materials

Materials most commonly considered for contact use include copper and copper alloys, silver, tungsten, and various sintered metals.

Unalloyed copper is seldom used for arcing-contact application, since it has very little resistance to electrical erosion and welding. However, it is widely used for contacts where its chief function is carrying current, rather than for interrupting it. Because of its high electrical and thermal conductivity and high thermal capacity, it is an excellent backing material for arcing contacts. In tap changing equipment, copper is used in most moving contacts, except the arcing tips. The contact resistance of copper, normally low when surfaces are clean, is adversely affected by the formation of surface film. This effect is not serious when the contacts operate under fairly high pressure and with wiping action.

Brasses, as used for contacts, are usually copper-zinc alloys. They are harder than copper and, therefore, more resistant to mechanical wear. For this reason they are used when the material must serve both as a conductor and a mechanical bearing. To a limited extent, they are used in arcing contacts at light loads.

Silver has high electrical and thermal conductivity, but has a thermal capacity somewhat less than that of copper. Its contact resistance is not seriously affected by surface films. For this reason silver or silver-faced contacts are used on equipment operated in air. For equipment which operates under oil, silver has little advantage over copper and has the added disadvantage of being attacked by sulphur and flaking off. Its resistance to arc erosion is not outstanding and therefore it is not used for interrupting heavy loads.

Tungsten is one of the most basic of contact materials. Its hardness and high melting point make it extremely resistant

to frictional wear and arc erosion. There are, however, a number of drawbacks to using tungsten in the pure state. Its electrical resistance is about 3.5 times that of copper; the specific heat is ⅓ that of copper; and the thermal conductivity is 45 percent that of copper. Clearly, then, it is not entirely satisfactory electrically or thermally.

Extreme hardness and brittleness make tungsten difficult to work with. For this reason and its high cost it is commonly used in composition with other metals. Because its melting point (3370 degrees C) is far higher than that of other metals, tungsten cannot be readily alloyed. It is usually combined with other metals by a process of powder metallurgy, known as sintering. The most common sintered materials as applied to electrical contacts are tungsten and tungsten carbide combine. with copper or silver.

In the sintering process, the metals to be combined are finely powdered, mixed together, and heated under pressure. For example, when copper and tungsten are combined, the powdered metals are mixed and then heated under pressure to about 1300 degrees C. At this temperature the copper melts and serves as a binder for the tungsten particles, resulting in a material combining the good properties of both metals.

A great number of combinations of sintered metals have been developed to give various contact qualities. Tungsten or tungsten-carbide combined with silver is used for arcing contacts operating in air. This material has the characteristic advantage of silver, being relatively free from the adverse effect of surface oxide. Tungsten or tungsten-carbide combined with copper makes up the most widely applied group of arcing materials used in equipment operating under oil.

The properties of sintered materials can be controlled over a wide range by varying the tungsten-to-copper ratio. In general, increasing the amount of tungsten increases the resistance to arc erosion, welding, and mechanical wear; it reduces the electrical and thermal conductivities and increases contact resistance. Conversely, if high conductivity is desired along with moderate resistance to arc erosion, the amount of tungsten is held to a minimum. The actual composition of the material in arcing contacts, as well as the size and shape of the contacts, is dependent upon actual operating conditions.

Laboratory tests measure effectiveness

To test tap changer contacts in actual operation would require many years of testing, and would involve a complicated and impractical test set-up. For these reasons, accelerated life tests are employed which shorten the time required for any particular test.

Tests made represent actual electrical, thermal, and mechanical conditions as nearly as possible. The vector diagram of Figure 2 shows that the interrupted current lags the switch voltage by 90 degrees. This is true regardless of the load power factor. Consequently, the switch voltage for test may be established by using a reactor in series with the load-interrupting contacts. Figure 3 shows a schematic diagram of a typical test set-up. An oscillograph is used to determine the switch voltage, length of arcing time, and length of transition time. Using the test set-up of Figure 3, it is possible to test two or more types of materials at one time, and obtain a comparison under exactly similar conditions. For preliminary comparison tests, as many as nine materials may be tested at one time by using different tips on the nine stationary contacts. By such comparison, many materials may be eliminated immediately as unsatisfactory.

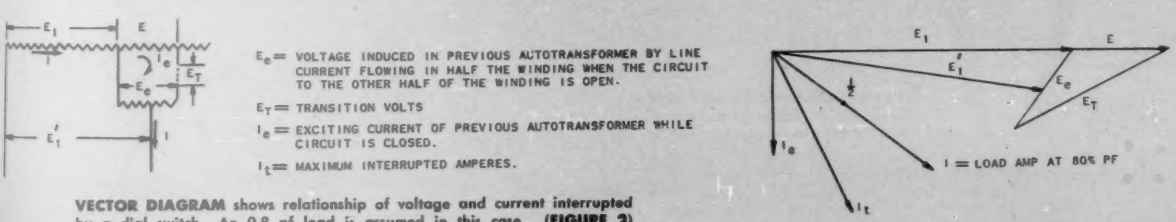
It might be supposed that a sufficient number of tests would enable determination of a formula for the amount of mass lost from a contact per operation. This is true for dc circuit interruption only. For ac circuit interruption, the accuracy of such a formula hinges entirely on the laws of probability. The amount of material released from a contact must be proportional to the energy of the arc, E×Q, where E is the voltage across the arc and Q the quantity of electricity passed by the arc. The quantity of electricity is:

$$Q = \int_{t_1}^{t_2} i\,dt$$

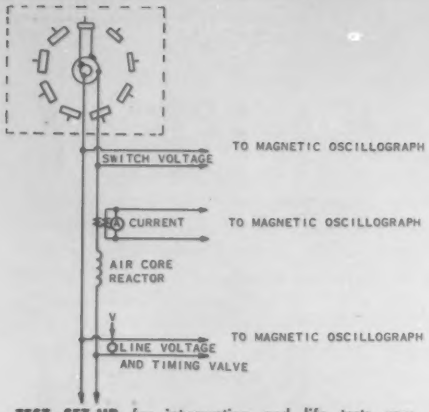
It is evident that the mass lost per operation per contact depends upon where in the cycle the circuit is interrupted, and also upon the polarity of the contact at the time of interruption, since the material loss is from the cathode in this case. Consequently, it is necessary to run each test for a minimum of 50,000 operations, preferably 100,000 operations, to obtain a reasonable average material loss per operation.

The material loss alone can determine the suitability of a material for use as a circuit interrupting contact, but further study is necessary to determine its qualifications for a particular application. For example, let us consider two materials, A and B. In one test both materials may have an approximately equivalent weight loss, but when tested at a lower current and high voltage, material A deteriorates very rapidly, whereas B is able to withstand many hundreds of thousands of operations without serious damage. In other words, each material selected as suitable for use must undergo a long series of tests over a wide range of voltages and currents to determine for which particular application it is superior to other materials.

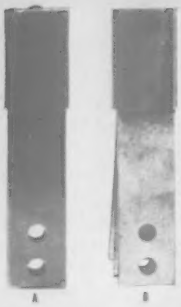
Visual inspection is also extremely important in determining the suitability of a material. Figure 4 shows two contacts of sintered materials which underwent identical tests. Both have lost approximately the same mass, but many cracks have appeared in A. Obviously, the intense heat generated in the arc tended to separate the sintered components in this case. Material B, however, exhibits no such cracking. Likewise, visual inspection alone can be rather misleading at times. This is especially true when comparing materials of different densities. The loss of material may appear to be about the same, but upon weighing it will be found that the percentage of material lost is greatly different.



VECTOR DIAGRAM shows relationship of voltage and current interrupted by a dial switch. An 0.8 pf load is assumed in this case. **(FIGURE 2)**

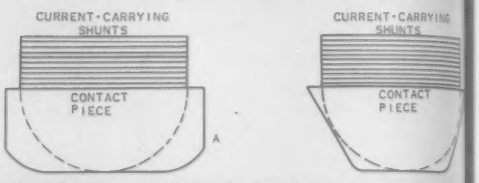


TEST SET-UP for interruption and life tests uses oscillograph to determine switch voltage and length of arcing time and transition time. **(FIGURE 3)**



COMPARISON between identically shaped contact fingers made of different sintered materials. **(FIG. 4)**

SHADED AREA "M" in the cylindrical contact finger diagram above is the mass which burns away due to arcing. **(FIGURE 7)**



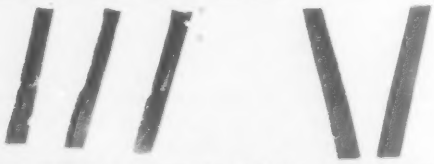
VARIATIONS from cylindrically shaped contact piece are used for different conditions of voltage and current interruption. Dotted lines show how contact in Figure 7 would appear. **(FIGURES 8a and 8b)**

Comparison tests provide final choice

The results of a preliminary test on five different materials are shown in Figure 5. All these stationary contacts were mounted on a tap changer at the same time, and underwent the same number of operations under exactly similar conditions. The contact pieces themselves are made of a highly conductive material, but since this material has very poor resistance to arc erosion, arcing tips of material exhibiting good arc-resisting properties were brazed in place. Figure 6 indicates why these arcing tips are necessary for heavy loads.

By comparison and elimination both on stationary and movable contacts the best material for each application is finally chosen. It now remains to use this material to best advantage to insure the longest possible life for the contact. An examination of the causes of arc discharge is helpful.

At the moment of circuit interruption, an extremely high potential gradient exists between the separating contacts. Such a gradient breaks down the insulating medium, in this case insulating oil, and the ionized medium thus presents a very low resistance to current flow. The heat generated in the arc then maintains this ionization until such time as separation of the contacts is great enough and the current flow small enough to discontinue ionization of the medium. Thus, we may attempt to reduce arcing by reducing the potential gradient between contacts, and by inserting a non-ionized medium between the contacts. Several methods of arc quenching are in use in high voltage switchgear, but in an oil immersed rotary switch such as a tap changer, extinction of the arc within the first one-half cycle eliminates the need for arc quenching. By proper physical design of contacts, the potential gradient between the contacts may be reduced.



TEST RESULTS of comparison test of five different sintered materials in arcing tips are shown above. Conditions and number of operations similar for all. **(FIGURE 5)**

STATIONARY contacts tested without and with arcing tip of sintered material are shown at left. **(FIG. 6)**

Consider first the stationary contacts. The arcing tip must necessarily have a rather sharp edge to allow the movable contact to slide on with a minimum of impact. However, a sharp edge creates the most severe potential gradient. By compromising between the two extremes, mechanical stresses due to impact may be kept within reason, and at the same time dielectric stress may be kept much lower than would be obtained with a very sharp angle.

The movable contact allows much more flexibility in mechanical design. It is well known that an electrode with a curved surface creates a comparatively low potential gradient at that surface. At the same time, mechanical conditions for minimum stress due to impact when making contact are very favorable. Conversely, a square cornered movable contact creates the poorest conditions, both electrically and mechanically. Certain factors preclude the use of an ideally curved contact surface such as that of Figure 7, necessitating a compromise between a minimum potential gradient and practical considerations.

Some possible variations of the ideally curved contact surface of Figure 7 are shown in Figures 8a and 8b. The proper design of these variations can provide contacts to give excellent service at any desired combination of voltage and current.

Ideally, contacts could be developed to give optimum performance for each individual rating of tap changer. In practice, a number of different sizes are used. At the lower limits of the smaller sizes, it is possible to use non-sintered material both to carry the current and to interrupt the arc. As the ratings increase, sintered materials are used almost exclusively for the arcing tips, both on the stationary and moving contacts. Only a few of the commercial sintered materials are used in tap changing equipment, since a very limited range of copper tungsten mixture is suitable for this particular application.

Sintered materials are quite expensive both because of the tungsten content and the specialized process of their manufacture. For this reason they are used as facing materials where the contacts are exposed to arcing, usually in combination with backings of copper, brass, etc. Economies of design, however, dictate in many cases that the entire contact piece be made of the sintered material, as in the movable contact fingers shown in Figures 1 and 4.

Efforts are continually being made to improve the quality of sintered materials as used in contacts, and to this end hundreds of tests are conducted each year to develop arcing contacts which give the longest possible uninterrupted service.

"ONE FOR THE BOOKS"

What is Exciter Response?

by **H. H. ROTH**
Motor-Generator Section
Allis-Chalmers Mfg. Co.

Brief review of this basic characteristic tells what it is and how it is determined.

RAPID GROWTH of electrical systems has created increased attention in the various factors which tend toward maintaining stable voltages under system faults or load changes. The change in voltage of an ac generator because of a sudden load change depends upon the generator, exciter and voltage regulator characteristics. Although exciter response is only one of the factors in improving system voltage stability, a clear understanding of the fundamentals of nominal exciter response is of assistance in the selection of the proper exciter for a particular application.

Exciter response is the rate of increase or decrease of the main exciter voltage when resistance is suddenly removed from, or inserted in, the main exciter field circuit.

The meaning of exciter response ratio can best be illustrated by reference to the graph. The first step in determining the response of a given exciter by test is made by taking an oscillogram showing the build-up of the exciter voltage from a point starting at the nominal collector ring voltage of the ac machine served by the particular exciter. Experience has shown that this build-up curve can also be taken from the exciter residual voltage to maximum ceiling voltage, since the slope of the build-up curve is the same at nominal collector ring voltage regardless of whether the transient starts at zero volts or at collector ring volts.

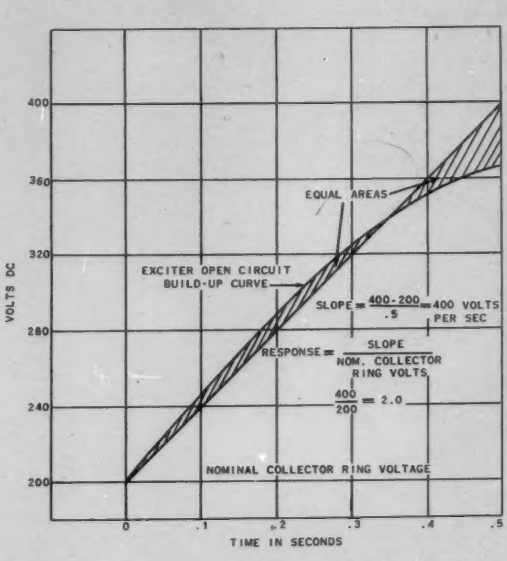
Response obtained graphically

The build-up curve is then plotted showing the exciter voltage as a function of time. Next, a straight line is drawn across the build-up curve as shown, so that the area between the build-up curve and the straight line below the point of intersection is the same as the area above the point of intersection within limits of zero to 0.5 seconds elapsed time, starting at nominal collector ring voltage of the ac machine.

The straight line is the average slope of the build-up curve in volts per second. This slope, divided by the nominal collector ring voltage, is the nominal response of the exciter. It is evident, therefore, that the nominal response of a given exciter changes with any change in the nominal collector ring voltage of the ac machine, since the slope of the build-up curve will change as the nominal collector ring is changed. For example, the curves in the illustration are based on a collector ring voltage of 200 volts. If, however, this exciter is applied to an ac machine requiring 250 volts nominal excitation the exciter response ratio would be lower, since 250 volts nominal excitation, the nominal exciter response would be lower, since the average slope would be determined from a point starting at 250 volts, where the build-up is less rapid.

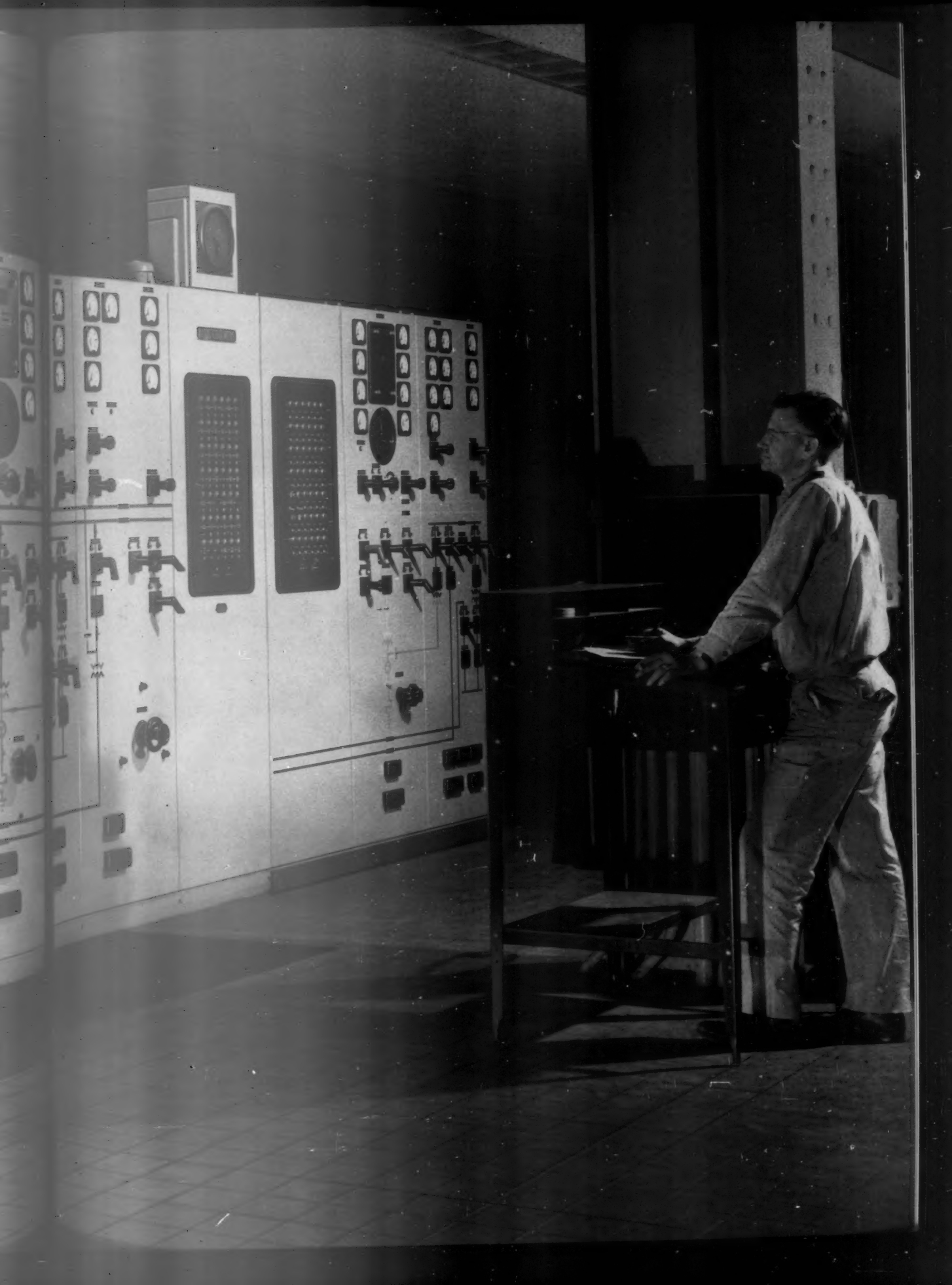
Standard main exciters have a nominal response of 0.5 except for synchronous condenser exciters, for which the standard nominal response is 1.0. When a speed response greater than standard is required, the design of the main exciter must be modified, and a separate constant voltage source of excitation may be required for the main exciter, usually in the form of a pilot exciter.

In considering over-all response of a complete generator or synchronous condenser installation, it must be understood that exciter response merely determines how quickly the exciter tends to increase or decrease the excitation of the ac machine upon a signal from the voltage regulator. The response of the ac machine to a change in its excitation is a different matter. The actual change in voltage of an ac generator because of a sudden change in its load depends upon several factors in addition to exciter response. Most important of these is the open circuit time-constant and the transient reactance of the ac machine. For machines having a high transient reactance, a higher nominal exciter response will greatly improve the over-all response of the unit. The greatest improvement from high exciter response is obtained with machines having a low transient reactance, or having a short time-constant.



MAIN DUPLEX CONTROL BOARD at a midwest utility reflects today's rising power demand. Initial installation consisted of six panels shown at left for controlling two 30,000-kw, 13,800-volt turbo-generators, 2400-volt auxiliary busses and alarm system. Three panels at right were added later to control an additional 30,000-kw generator, 2400-volt auxiliary bus and alarm system. Machines are in unit connection with their respective transformers which supply the 69-kv main and maintenance busses.

A-C Staff Photo



SWITCHGEAR CONTROL for Synchronous Motors

by W. E. SCHWARTZBURG and C. STRAUB[1]
Switchgear Section
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The right switchgear control for large synchronous motors can be selected by following these recommendations.

SELECTING PROPER CONTROL EQUIPMENT for large synchronous motors requires consideration of several critical factors having a direct bearing on the successful and safe operation of the motor and the machine to be driven. Specifying proper equipment for coordination between machine, motor, and control can begin only after the requirements of the machine to be driven have been determined and the desired motor characteristics are known.

In addition to starting and stopping duty, the control must also provide necessary protection for the motor against overloads, internal faults and any other abnormal conditions which might seriously impede efficiency and safety or cause damage. How then does the engineer applying the motor determine what control equipment will be needed and how it will function?

First select breaker rating

It should be pointed out that there are many synchronous motor applications 5,000 volts and below, where total line capacity is small enough and where starting and stopping interruptions are frequent, for which industrial control class of equipment can be used to a definite advantage,* particularly in view of its lower cost. However, this discussion covers only metal-clad switchgear starting equipment.

One of the basic problems in the selection of the control equipment is to determine the correct size of the circuit breaker, remembering that the size of the breaker is not always determined by the size of the motor. In addition to selecting a breaker having voltage and continuous current-carrying capacity ratings at least equal to and preferably exceeding the circuit voltage and the maximum ampere load of the motor, it is also necessary that the kva interrupting capacity, maximum ampere interrupting capacity, and momentary ampere ratings of the circuit breaker be fulfilled. These values should at least equal and preferably exceed the maximum kva to be interrupted under short circuit conditions, the maximum short circuit amperes to be interrupted, and the initial total rms short circuit current. Obviously, the size of the motor will determine the continuous current rating of the breakers. Standard continuous current ratings of circuit breakers are 600, 1200, and 2000 amperes.

The kva which the breaker will be called upon to interrupt at the time of a fault is dependent upon conditions quite often beyond the control of the user. In most motor applications, power is purchased from the local utility. Sometimes the voltage of the incoming line is the same as the utilization voltage, in which case no transformation of voltage is required. In other instances power is bought at a sub-transmission voltage (up to 33 kv) or a tap is made from the transmission line itself, in which case the voltage may be much higher. Where power is purchased at the utilization voltage, the motor circuit breaker must interrupt whatever kva the utility's lines deliver under short circuit conditions. In an application of this type the utility will normally specify the maximum short circuit kva and the current which the breaker must be capable of handling, since the breaker is not only protecting the motor but is also affording protection to the utility's feeder.

As soon as the required motor characteristics are known, it is a good idea to consult the power company. Through cooperation with the utility's engineers during the preliminary engineering stage, the user is assured of an ultimate economical and efficient installation.

For example, it may be found to be more economical to purchase power at the sub-transmission voltage and buy the equipment necessary to transform it to the utilization voltage than it would be to have the utility supply power at the desired voltage. In a case of this nature it is usually found that the kva which the breaker will have to interrupt will be less when supplied from a transformer bank than when not. This is due to the added reactance presented by the transformer.

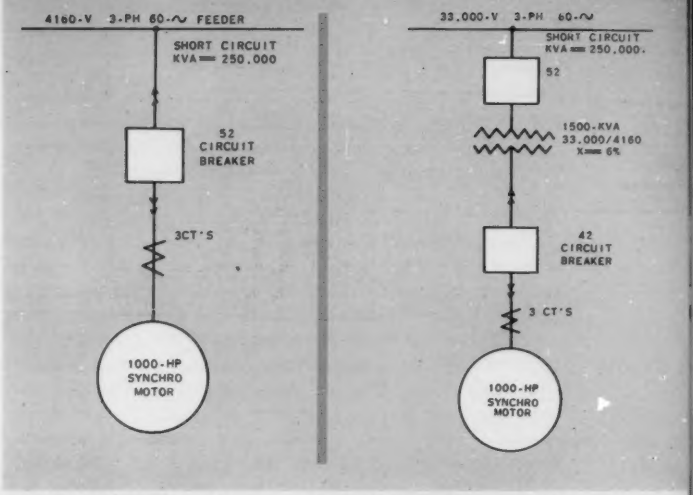
To show how reactance affects the selection of the circuit breaker let us assume that a certain application requires the installation of a 1000-horsepower, 4160-volt, three-phase, 60-cycle synchronous motor. In the first method (Figure 1) the power company will supply the power from a 4160-volt feeder capable of delivering 250,000 kva under short circuit conditions. In this application the user's breaker must be rated 250,000 kva, 1200 amperes, 5000 volts.

In the second method (Figure 2) power is purchased at 33,000 volts and then stepped down to the desired 4160 volts. If the utility's sub-transmission line in this case is capable of supplying 250,000 kva under short circuit conditions, what size breaker would be needed on the secondary side of a 1500-kva transformer? The standard 1500-kva, 33,000-4160-volt transformer will have an impedance of approximately six percent. By using the percentage system the maximum kva which the transformer will pass can quickly be determined.

With 100 percent kva, 100 percent voltage and 100 percent current the line will have 100 percent impedance. The 1500-kva transformer has six percent impedance on its own base (1500 kva). The percent impedance on the same base as the line (250,000 kva) will be equal to the ratio of the capacity of the transformer to the common base. Therefore, $1500/250{,}000 = 6$ percent/X which means that the transformer will offer 1000 percent impedance on the 250,000-kva base. Adding the two impedances the total impedance in the circuit (neglecting impedance of the cables and the fault) will be 1100 percent. Converting this percentage to actual

[1] Mr. Straub is now with the Bureau of Ships and Yards, Navy Dept., Washington, D. C.

* See "Coordinating Controller and Breaker Ratings," by T. H. Bloodworth and T. B. Montgomery, *Electrical Review*, 2nd Quarter 1950. Also "A Survey of Modern Motor Starters," by John Baude, *Electrical Review*, 1st Quarter 1947.



MOTOR STARTING breaker must interrupt full short circuit capacity of line. Modern, high-capacity lines may make method costly. **(FIG. 1)**

LOW DISTRIBUTION rates often reduce starting equipment cost by using a standard step-down transformer with a lower capacity breaker in secondary circuit. **(FIGURE 2)**

kva, 250,000/1100 percent X 100 it is found that the maximum symmetrical kva is 22,700. Thus a 25,000-kva breaker is all that is required, although a 50,000-kva breaker would be used, since it is the smallest rating manufactured for present-day metal-clad switchgear. Here the user has the advantage of lower power cost and lower motor breaker cost, somewhat offset, however, by the additional cost of the 1500-kva transformer and auxiliaries.

A quick and approximate check for this problem is to assume the feeder is capable of delivering infinite kva into the fault. If this is true, then the actual short-circuit kva is equal to the reciprocal of the transformer impedance multiplied by the kva of the transformer which would be (1500 kva) (1/.06) or 24,990 kva.

In both of the above examples a 5000-volt circuit breaker with a continuous current-carrying capacity of 600 amperes would be used (although the motor full-load current is 108 amperes, and the smallest standard 5000-volt breaker manufactured in metal-clad switchgear is rated 600 amperes). However, in the first case a breaker having an interrupting capacity of 250,000 kva would be needed, whereas in the second illustration a breaker rated 50,000 kva could be used. From the above, it is obvious, therefore, that the size of the motor alone does not determine the rating of the circuit breaker.

Starting method comes next

When the size of the breaker has been determined the problem of what type of starting to use presents itself. Can the motor be started on full voltage or will reduced voltage starting have to be employed? What factors determine whether a motor can be started "across the line"? Must a motor that is going to be started on full voltage be specially designed or can any synchronous motor stand full voltage starting? In what manner is the reduced voltage to be obtained — autotransformers, resistors, reactors, taps on the power transformer, or should a special part winding starting motor be specified?

In any motor application the cost of the control equipment will be minimized if full voltage starting is used. Across the line starting does not pose an undue burden on the motor designer, for motors larger than 20,000 horsepower have been built for full voltage starting. Therefore, full voltage starting should be used wherever possible. What then is the limitation on across the line starting?

In the majority of cases the limiting factor is voltage drop. The high starting currents (which may be as great or greater than five times the motor's normal full load current) can cause an objectionable IR drop. Although in some instances the sudden application of full voltage torque cannot be tolerated by the mechanical drive, normally the only limitation is the voltage drop and its adverse effect on the distribution system.

Frequently the power company has specific regulations governing the size of the motor which may be started across the line. So far as the motor being started is concerned, the voltage drop is of no consequence (provided sufficient torque is developed) but other customers served by the same feeder may be subjected to an objectionable dip in voltage every time the motor is started. If these voltage dips are of sufficient magnitude, undervoltage relays may trip and other synchronous motors on the line may drop out of synchronism. Lamp flicker will also occur. The maximum size motor that can be started on full voltage depends upon the size of the feeder and the system supplying the power. Thus central stations or industries generating their own power who do not have to consider other users can start larger motors on full voltage.

The three most commonly used methods of reduced voltage starting are autotransformer, resistor, and reactor. When considering any method of reduced voltage starting it should be remembered that the starting torque will be less than that obtained with across the line starting. It is also well to remember that the load does not affect the magnitude of the

COMPARISON OF CURRENT-TORQUE STARTING CHARACTERISTICS FOR SYNCHRONOUS MOTORS

METHODS OF STARTING	STARTING CURRENT DRAWN FROM LINE AS % OF FULL-LOAD CURRENT	STARTING TORQUE AS A % OF FULL-LOAD TORQUE
Connecting Motor Direct to Line Full-Load Potential	600	125
Autotransformer 80% Tap	380	80
Resistor or Reactor Starter to Give 80% Applied Voltage	480	80
Autotransformer 65% Tap	250	53
Resistor or Reactor Starter to Give 65% Applied Voltage	390	53
Autotransformer 50% Tap	120	32
Resistor or Reactor Starter to Give 50% Applied Voltage	350	32

GENERAL COMPARISON OF STARTING WITH DIFFERENT REDUCED VOLTAGE STARTERS

CHARACTERISTIC	AUTOTRANSFORMER TYPE	PRIMARY RESISTOR TYPE	REACTOR TYPE
Starting Line Current at Same Motor Terminal Voltage	Least	More Than Autotransformer Type	
Starting PF	Low	Light	Low
Quantity of Power Drawn from Line During Starting	Less	More Than Autotransformer Type	
Torque	Torque Increases Slightly with Speed	Torque Increases Greatly with Speed	
Torque Efficiency	Autotransformer Starter Provides Highest Starting Torque of Any Reduced Voltage Starter for Each Amp Drawn from the Line.	Low	Low
Smoothness of Acceleration	Motor Is Momentarily Disconnected from Line During Transfer from Start to Run.	Smoother. As Motor Gains Speed, Current Decreases. Voltage Drop Across Resistor or Reactor Decreases. Transfer Is Made with Little Change in Terminal Motor Voltage.	
Cost	Higher	Low in Small Sizes, Otherwise Equal	Equal
Ease of Control	Equal	Equal	Equal
Maintenance	Equal	Equal	Equal
Safety	Equal	Equal	Equal
Reliability	Equal	Equal	Equal

CURRENT TORQUE starting characteristics for synchronous motors and comparisons of starting conditions associated with the three most commonly used types of reduced voltage starters are shown in the above tables. Performance characteristics depend on starter design. **(FIGURE 3)**

starting current, though acceleration time is increased by load. To show how starting torque varies with the different methods refer to Figure 3.

Autotransformer starting

The autotransformer type starter is very often used since it gives the highest starting torque of any reduced voltage starter for each ampere drawn from the line during the starting period. Figure 4 shows the line current plotted against time for a synchronous motor started on full 80 percent and 65 percent voltage (the reduced voltage being obtained with an autotransformer). With an autotransformer the starting current, kva, and starting torque vary as the square of the voltage at the motor terminals. For example, if a certain motor has 400 percent locked rotor current and 100 percent starting torque on full voltage, with an 80 percent tap the locked rotor current would be (80 percent)^2 x 400 percent = 256 percent. Starting torque would be (80 percent)^2 x 100 percent = 64 percent. In addition, the magnetizing current of the transformer would add approximately 25 percent to the motor locked rotor current, making the total line input approximately 281 percent of full load kva.

Basically an autotransformer starter consists of a tapped autotransformer with circuit breakers which are arranged to connect the motor to the desired reduced voltage tap during starting and to remove the autotransformer from the circuit when the machine has accelerated to the desired speed. The autotransformer is designed for intermittent duty and cannot be left connected to the line after the starting period, since it cannot dissipate its noload losses. The autotransformer is provided with taps for starting the motor on 65 percent or 80 percent of the line voltage. For larger size motors an additional tap is provided for starting at 50 percent voltage. The connections of an autotransformer starter are shown in Figure 5.

There are two methods of connecting an autotransformer in a synchronous motor starting circuit: open transition sequence or closed transition sequence. In the open sequence circuit the motor is completely disconnected from the line for a brief period during the starting cycle. The circuit breakers are automatically operated as shown in Table A, Figure 5. Under certain conditions this method of starting might be objectionable because of the transient current produced when the line breaker is closed.

The magnitude of this transient current can be reduced by using the closed sequence method of starting. This is accomplished by operating the circuit breakers as shown in Table B, Figure 5. In this method of starting, the motor is connected to the line through the reactance of the autotransformer and the current does not rise to the value encountered in the open sequence method.

The resistor type starter

Resistor starting consists of connecting the motor to the line through a series resistor in each phase. To accelerate the motor, switches for short circuiting the starting resistor are engaged gradually to increase the line current to the maximum value necessary to start the load. This method avoids the objectionable transient condition of the open sequence autotransformer starter during the switch from start to run because the motor is never disconnected from the line. Figure 6 shows line current plotted against time for a synchronous motor starting a loaded centrifugal pump with resistor starting.

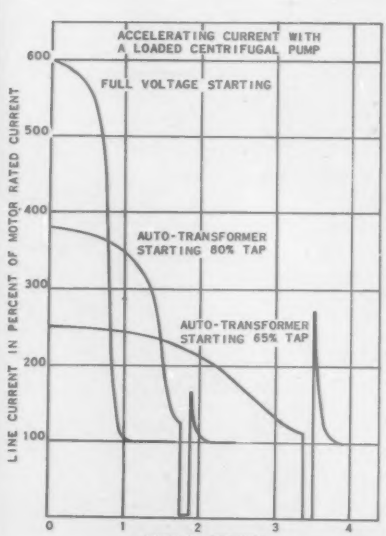
The line current in this method of starting is proportional to the applied motor voltage. The starting torque is reduced proportionally to the square of the applied motor voltage. Figure 7 shows the circuit employed in resistor type starting.

Reactor type starter

Reactor type starting possesses desirable characteristics which make its application attractive in some cases. It is similar to resistor type starters and may utilize the same switching arrangement. The reactor may not be short circuited in steps as the resistor; however, a smooth acceleration can be obtained through the use of a series reactor. A comparatively long accelerating time may be necessary since the starting torque may be low, as shown in Figure 8.

An increase in voltage results at the motor as it comes up to speed mainly because of the change in motor impedance. A slight additional increase in terminal voltage is obtained as the motor reaches synchronous speed because the reactor swings out of phase with the terminal voltage of the motor as the motor power factor increases near full speed. The torque and current vary with the reduction of the voltage in the same manner as in resistor starting.

The costs of starting duty autotransformers and reactors for a given machine are not far different. However, the total



EFFECT of autotransformer taps on line current drawn when starting a synchronous motor is plotted above. **(FIGURE 4)**

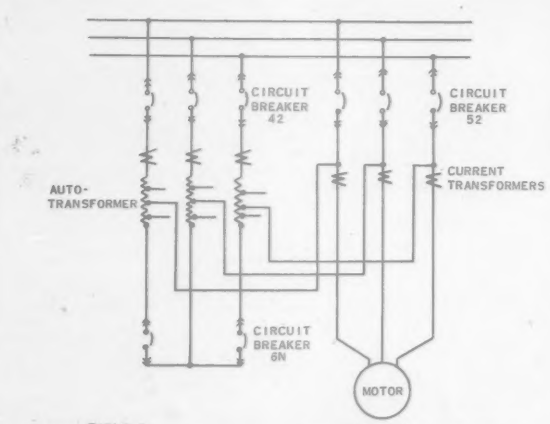


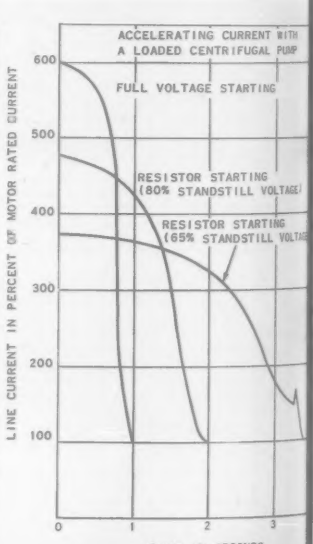
TABLE A
SEQUENCE - OPERATION

OPERATION		BREAKER		
		42	6N	52
STARTING	1	CLOSED	CLOSED	OPEN
	2	OPEN	OPEN	OPEN
RUNNING		OPEN	OPEN	CLOSED

TABLE B
SEQUENCE - CLOSED TRANSITION

OPERATION		BREAKER		
		42	6N	52
STARTING	1	CLOSED	CLOSED	OPEN
	2	CLOSED	OPEN	OPEN
	3	CLOSED	OPEN	CLOSED
RUNNING		OPEN	OPEN	CLOSED

DIAGRAM SHOWS circuit connections of an autotransformer starter. Tables indicate sequence of operation for both open and closed transition starting. **(FIGURE 5)**



LINE CURRENT of a synchronous motor during starting with series resistor is shown above. **(FIGURE 6)**

equipment involved with reactor starting may be much less because of the simple switching system employed. This is true especially when the reactor is placed in the neutral of the Y-connected motor as shown in Figure 9, because the reactance of the motor winding is between the line and the reactor, eliminating the need of high interrupting capacity in the two pole breaker which short circuits the reactor for running duty. The power loss in large resistors often swings the preference in favor of a reactor starter when considering these two types. When the motor voltage is 2200 volts and above, it is difficult to suitably insulate series resistors.

The final choice of equipment for starting a synchronous motor will be influenced by the overall cost spread over a period of many years. It is difficult, if not impossible, to make a positive statement as to which starting method is the most economical, since local conditions present many varied problems.

When the engineer has decided upon the method of starting, the next step is to write a specification covering the equipment necessary for the protection and control of the motor. The NEMA Standards for Power Switchgear Assemblies (Publication SG5, 1950) offers a great deal of useful information and is recommended reading for any engineer planning to install motor starting equipment. These standards recommend that the following equipment be furnished. The list includes only the minimum equipment required for any synchronous motor switchgear unit.

A metal-clad unit which shall consist of the following for both full voltage and reduced voltage starting:

(a) 1 — Hinged front panel.
(b) 1 — Power circuit breaker, three pole, single throw, electrically operated with closing relays.
(c) 1 — Circuit breaker position changing mechanism.
(d) 1 — Set of primary disconnecting devices.
(e) 1 — Set of secondary disconnecting devices.
(f) 3 — Current transformers, single secondary.
(g) 1 — Control circuit cutout device.
(h) 1 — Set of three-phase insulated copper buses rated 1200 amperes minimum.
(i) 1 — Set or three-phase insulated connections, current-carrying capacity equal to that of the power circuit breaker.
(j) 1 — Set of terminal blocks, small wiring, ground bus and control buses where required.
(k) 1 — Set of automatic shutters provided on all units rated 50,000 kva and above.
(l) Provisions for terminating cables.
(m) 1 — Ammeter, single phase.
(n) 1 — Indicating wattmeter or varmeter.
(o) 1 — Field ammeter with shunt.
(p) 1 — Rheostat operating mechanism or control switch.
(q) 1 — Field application and field protective equipment.
(r) 1 — Single phase time delay undervoltage protective equipment.
(s) 3 — Single phase overcurrent relays, direct current trip complete with test facilities.
(t) Necessary thermal relays as required for overload protection.
(u) 1 — Control switch with indicating lights.

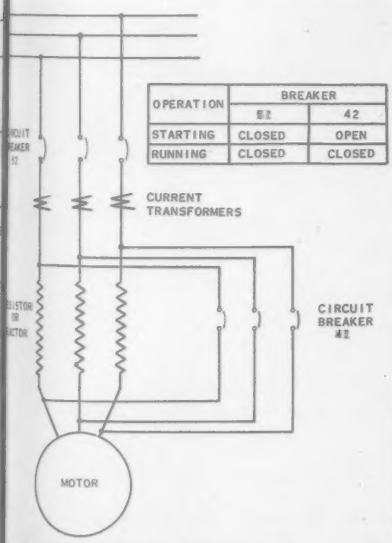
The above list shows the equipment that is necessary for starting a motor but does not discuss the purpose or function of each device.

The ac ammeter indicates to the operator the current being consumed by the motor and the dc ammeter indicates how much current is being used for exciting the synchronous motor field. By varying the field current with the field rheostat the motor can be overexcited or underexcited, enabling it to operate with either a leading or a lagging current for power factor correction when desired.

Although either a wattmeter or varmeter is listed by NEMA, it is preferable to include both a power factor meter (or varmeter) and a wattmeter to enable the operator to determine at what power factor the motor is operating and whether it is taking leading or lagging vars.

Relays are key points of motor protection

Protection for a synchronous motor is obtained with various types of relays which must sense when the motor is being abused or operating under abnormal conditions. When operating in synchronism, the squirrel cage or amortisseur winding



SERIES RESISTOR or reactor starting circuit is shown above. Table indicates the sequence of breaker operation. **(FIGURE 7)**

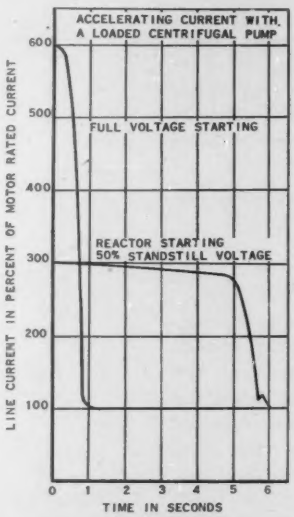
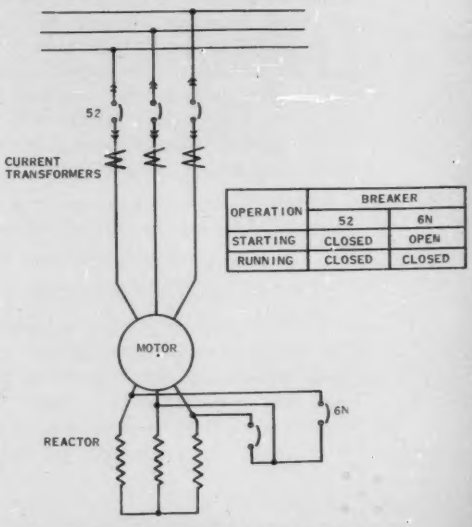


DIAGRAM CHARTS accelerating time of reactor and full voltage starting for a synchronous motor. **(FIGURE 8)**



NEUTRAL REACTOR starting circuit shown above lowers equipment cost because of its simplicity. **(FIGURE 9)**

does not carry current and no protection is required for this winding. However, when operating out of synchronism, as in the starting period, a heavy current flows in this winding. If this operation is prolonged for an excessive length of time, overheating and failure will eventually occur. Motor operation out of synchronism for extended periods may result from a failure to start, a long starting period, pull-out on overloads, low voltage, or failure of the motor to resynchronize. These conditions may occur on any synchronous motor application, so protective equipment furnished should give adequate protection to the squirrel cage as well as to the stator winding of the motor.

Thermal relays are usually furnished for safeguarding the stator winding against prolonged overloads, allowing the motor to carry the intermittent overloads for which it is designed. Thermal relays, however, are designed to follow the heating curve of the stator winding and they do not adequately protect the squirrel cage winding. So induction overcurrent relays with a long time delay are usually furnished to protect the squirrel cage winding from locked rotor currents.

Short circuit protection for the motor is obtained by having instantaneous overcurrent trip attachments on the thermal relays or the overcurrent relays. These instantaneous trip attachments are usually set for a current value slightly above the locked rotor current of the machine.

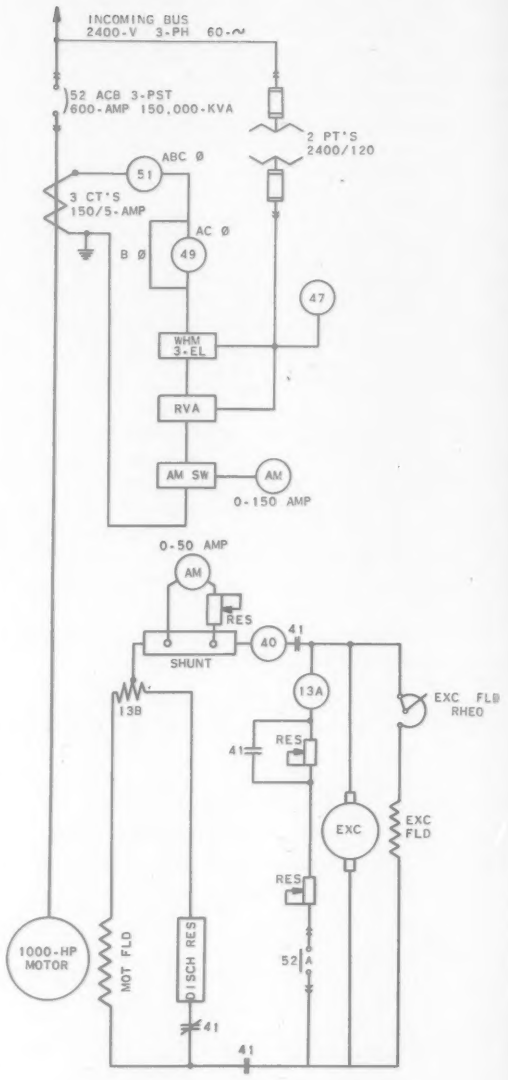
Time delay undervoltage protection is provided with ac undervoltage relays for disconnecting the motor from the line upon loss of voltage or on low line voltage. This relay has a time delay to prevent shutdown on temporary dips in voltage. With reduced voltage starting, the relay should be connected to trip both the starting and running circuit breakers.

Another important job for a synchronous motor control is that of properly applying the dc field to the motor. During the starting period the dc field winding of the motor is shorted through a discharge resistor. This discharge resistor limits the high induced voltage at the field terminals and affects the pull in torque of a motor to a certain extent. When the motor reaches synchronous speed, the field application relay disconnects the discharge resistor from the motor field and applies dc power and the motor is synchronized. If for some reason the motor is overloaded or a voltage dip occurs on the line, and the motor pulls out of step, the field application relay will remove the dc power supply from the field of the motor to reduce disturbances on the power line and strain on the motor and driven apparatus. The relay will resynchronize the motor if the conditions causing pull-out have been corrected. However, if conditions will not permit resynchronizing, the motor will be shut down by the incomplete sequence relay device before the motor field fails. The field failure relay closes its contact on field failure and energizes the incomplete sequence relay which will open the motor circuit breaker.

NEMA Standards recommend that differential protection be provided for motors rated as follows:

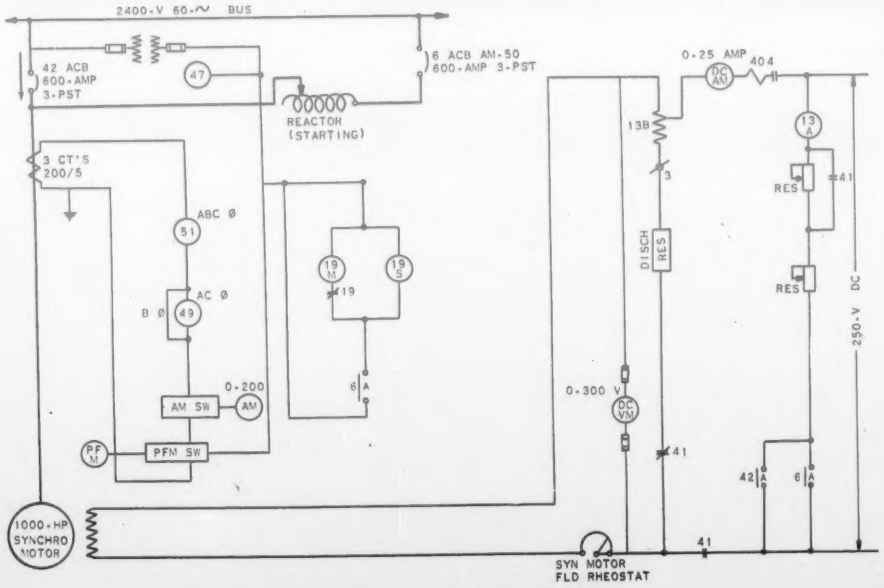
2200 to 5000 volts — 1500 hp and above
Above 5000 volts — above 500 hp

The additional equipment necessary for differential protection are three current transformers at the machine neutral, three current transformers located in the switchgear unit, and three single-phase differential relays. Differential relays will operate when there is a phase-to-phase or phase-to-ground short circuit. These extremely fast and sensitive relays afford



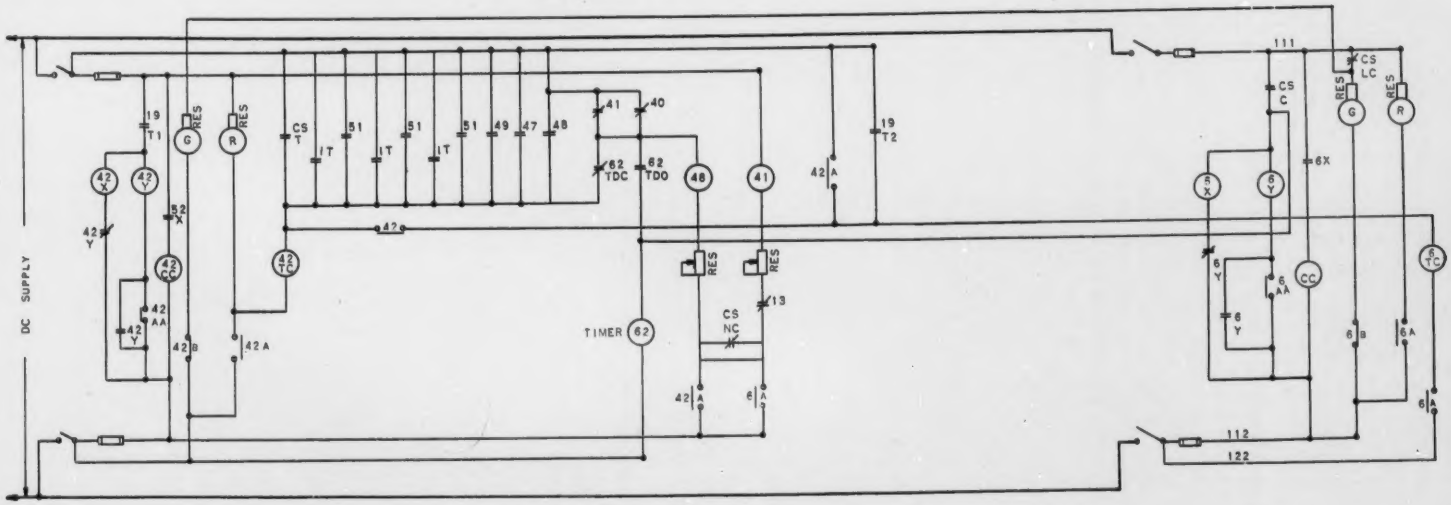
AM - AMMETER
VM - VOLTMETER
AM SW - AMMETER SWITCH
VM SW - VOLTMETER SWITCH
WHM - WATTHOUR METER
RVA - VAR METER
13 - FLD APPL'N RELAY
40 - FLD FAILURE RELAY
41 - FLD CONTACTOR
47 - REV. PHASE AND UNDER-VOLTAGE RELAY
48 - INCOMPLETE SEQ RELAY (NOT SHOWN IN DIAGRAM)
49 - THERMAL RELAY 2-ELEMENT
51 - OVERCURRENT RELAY
52 - AIR CIRCUIT BREAKER
A - ACB AUX SW - OPEN WHEN BREAKER IS OPEN

LINE AND SCHEMATIC diagram shows the arrangement of components for full voltage starting. **(FIGURE 10)**



TYPICAL REDUCED VOLTAGE starter arrangement for a synchronous motor is shown in the above single line and schematic diagram. **(FIGURE 11)**

6	-	AIR CIRCUIT BREAKER
42	-	AIR CIRCUIT BREAKER - RUNNING
AM	-	AC AMMETER
DC AM	-	DC AMMETER
DC VM	-	DC VOLTMETER
PFM	-	POWER FACTOR METER
WHM	-	WATTHOUR METER
51	-	OVERCURRENT RELAY
47	-	REVERSE PHASE RELAY
19	-	TIMING RELAY
52 CC	-	ACB CLOSING COIL
52 TC	-	ACB TRIP COIL
52 XY	-	ACB CONTROL RELAYS
52A	-	ACB AUX SWITCH - NORMALLY OPEN
52B	-	ACB AUX SWITCH - NORMALLY CLOSED
CSC	-	CONTROL SWITCH - CLOSE
CST	-	CONTROL SWITCH - TRIP
CSLC	-	CONTROL SWITCH - LAMP CUTOUT
CSNC	-	CONTROL SWITCH - NORMALLY CLOSED
13	-	FIELD APPLICATION RELAY
13A	-	POTENTIAL COIL
40	-	FIELD FAILURE RELAY
41	-	FIELD CONTACTOR
48	-	FIELD INCOMPLETE SEQUENCE ELEMENT
62	-	AUXILIARY TIMING RELAY



maximum protection to the motor during short circuit conditions, since they trip the circuit breaker before serious damage can be done to the steel in the stator.

When deciding whether the additional cost for differential relaying can be justified for a particular motor, not only the value or importance attached to that motor must be considered, but also how the remainder of the power system would suffer if this motor was not disconnected quickly when in trouble.

More switchgear may be needed

The equipment necessary for starting a motor across the line was listed previously. However, when starting a motor on reduced voltages, additional switchgear is needed as shown in Figures 5, 7, and 9. NEMA recommends that the following additional equipment be furnished:

(a) 1 — Reactor or autotransformer compartment.

(b) 1 — Starting unit for reactor start or
2 — Starting units for autotransformer start.

(c) Necessary time delay and auxiliary relays as required by the starting method.

Item (a) consists of a compartment, usually of the same depth and height as the other switchgear units in the lineup. Each of the starting units, Item (b), consists of the same equipment as listed in Items (a) to (k) of the breaker unit for full voltage starting.

To best illustrate how this equipment is utilized, refer to Figure 10 and Figure 11. In Figure 10, when the operator closes breaker 52 by energizing relays 52X and 52Y through the close contact of the control switch, the motor accelerates on its squirrel cage winding until it reaches approximately 95 percent of synchronous speed. At that time the polarized field application relay, device 13, applies dc power to the motor field by closing its contact in series with the coil of the field contactor, device 41. When 41 closes, the machine should then pull into step; however, if for some reason this does not happen, device 48 (the incomplete sequence relay) picks up and trips breaker 52. This particular motor is protected by the normal induction overcurrent, device 51, and thermal relays, device 49, listed previously, as well as by a reverse phase and undervoltage relay, device 47.

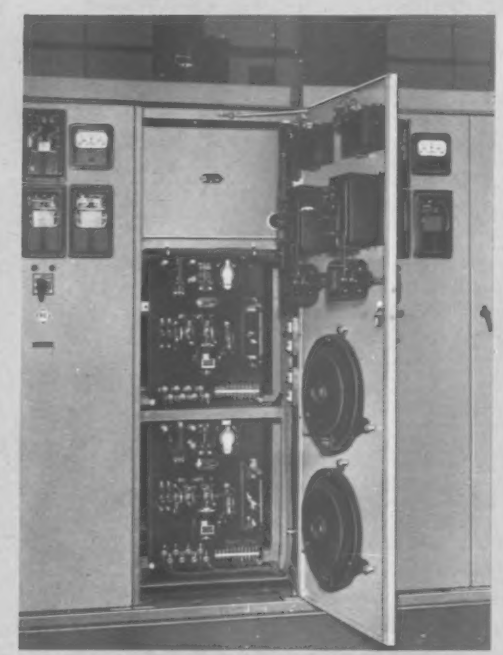
Figure 11 shows a single line and schematic diagram of a reactor starter. The operator closes breaker 6 which energizes timer device 19. The motor accelerates on reduced voltage until the timer closes the running breaker 42 which, when closed, trips the starting breaker. The motor then continues to accelerate on full voltage until the field application relay picks up.

From there on, the operation is similar to the full voltage starter. An added feature shown in Figure 11 is the prevention of resynchronizing. This is accomplished through the use of timer 62. It is to be noted that upon a field failure the circuit breaker is tripped by device 40, which is the field failure relay. This feature is found on all types of starters.

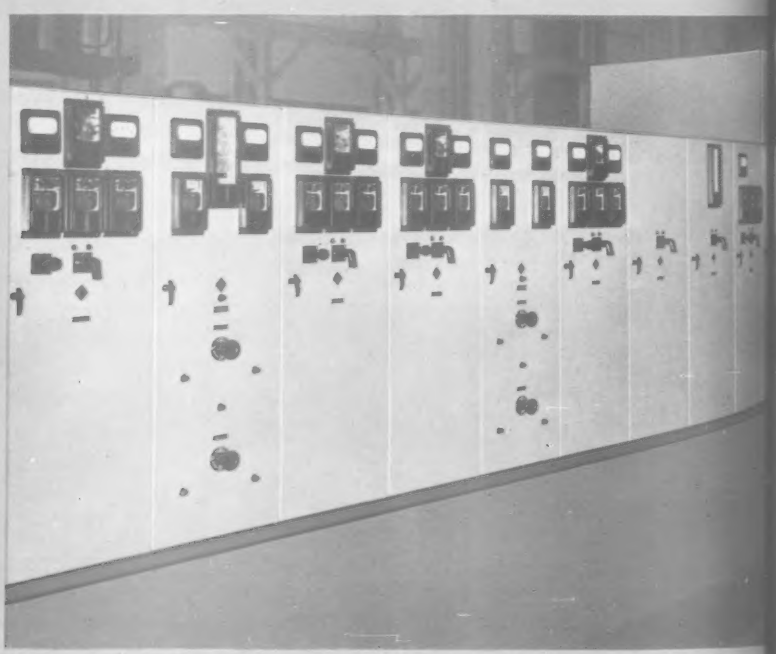
Figure 12 shows a switchgear auxiliary unit containing two field application panels on which are mounted the following devices:

13 — Field application relay
48 — Incomplete sequence relay
41 — Field contactor
40 — Field failure relay

On the hinged panel are the two exciter field rheostats, the dc ammeters, and relay 47. Figure 13 shows a typical complete lineup of switchgear comprised of two incoming line units, an auxiliary transformer feeder, and four full voltage motor starters.



METERING AND CONTROL devices of this auxiliary unit used to control two 300-hp synchronous motors are mounted on swinging panel. **(FIG. 12)**



METAL-CLAD SWITCHGEAR lineup shown above controls three 300-hp and one 1000-hp synchronous motors. The lineup includes the incoming line units, auxiliary power supply and complete motor control. **(FIGURE 13)**

FERTILE PLAINS transformed from semi-arid wasteland lie just beyond these vertical, splash-proof motors driving vertical, condensate circulating pumps at a recently completed power plant in the southwest. The 440-volt, 75hp, 1750-rpm squirrel cage motors driving 10 x 4-inch, 600-gpm, 220-ft. head pumps help generate the power for irrigation which the surrounding lands need during the recurring, long, dry spells. Scattered clumps of forage of a few years ago were transformed into rich pastures and fertile soil which now produces a wide variety of foodstuffs.

A-C Staff Photo

GRAPHICAL DIFFERENTIATION

. . . Done With a Mirror

by
J. M. RAMRATH
Allis-Chalmers Mfg. Co.
Boston, Mass.

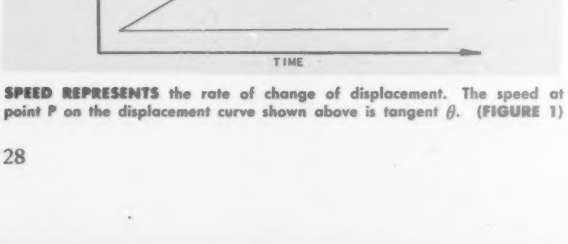
Graphical method of curve differentiation provides a ready solution for a difficult design problem.

DESIGNERS OF CERTAIN TYPES of apparatus are frequently called upon to evaluate non-linear displacement performance curves.

The apparatus itself may be made to record its own time-displacement characteristic by the application of curve-drawing instruments, such as the circuit breaker analyzer or speedgraph, used on power circuit breakers.

From these time-displacement curves the designer must derive speed and acceleration curves to assist him in evaluating his design problems. The speed, or velocity curve, which is the first differential of the displacement curve, or a curve of instantaneous values of the slope of the displacement curve, is useful in studying functional coordination of the apparatus. The acceleration curve, which is the second differential of the displacement curve, or the curve of rate of change of velocity, is needed to evaluate the forces required to accelerate and decelerate the masses involved so that they will move along the desired displacement curve.

If a mathematical relationship or an equation is available for the given displacement curve, and if the analyst's differential calculus is sound, formulae for the velocity and acceleration curves may be developed readily. If not, the problem must be solved by some graphical method of approximation, if one is available.



SPEED REPRESENTS the rate of change of displacement. The speed at point P on the displacement curve shown above is tangent θ. **(FIGURE 1)**

Without calculus

Here is a method for graphical differentiation which is exceedingly simple, yet accurate. It is such an effective tool for solving problems of this nature that it may be given preference over calculus.

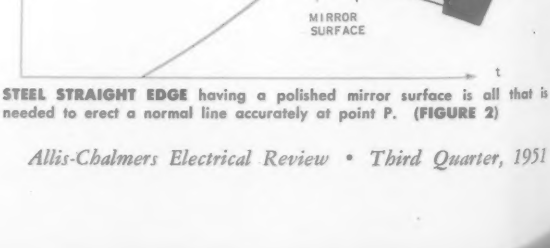
Figure 1 shows a non-linear curve having space s as the ordinate and time t as abscissa. The velocity at point P is the slope of a tangent to the displacement curve at that point.

$$\frac{ds}{dt} = \tan\theta = \text{instantaneous velocity}$$

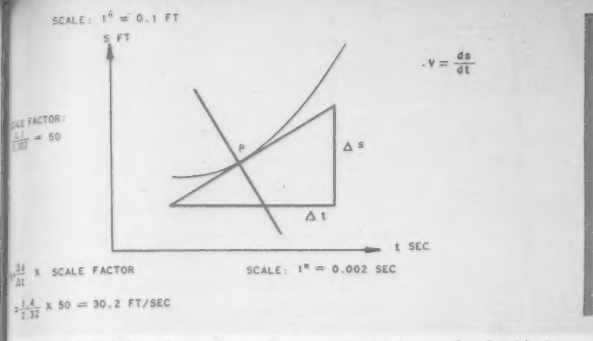
Thus the fundamental problem in the graphical method is to accurately draw a tangent to a curve even in places of rapid curvature changes.

The only tool required, in addition to the usual drafting instruments, is a steel straight edge having a vertical surface polished to a mirror finish.

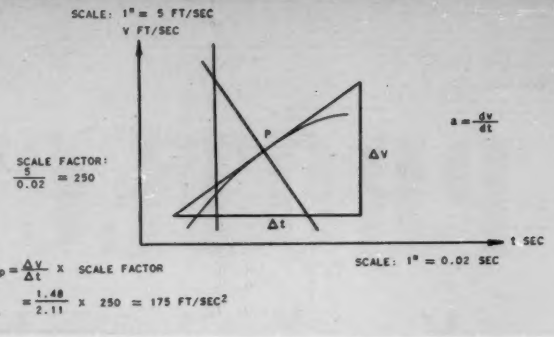
The mirror straight edge is placed in an approximately normal position across the curve as at point P in Figure 2. It is then rotated slightly about that point until the mirror image appears to be a perfectly smooth continuation of the real curve immediately in front of the mirror. If the curve lines up accurately, the straight edge will be normal to the curve at point P and the normal line is drawn along its edge as is shown in Figure 2. The next step is to draw a perpendicular line at point P on the normal. Then this line is an accurately oriented tangent to the curve at that point as shown in Figure 3. A slope triangle is then completed, drawing Δs and Δt as adjacent sides and using the tangent to the curve as the hypothenuse. For reasons of accuracy, this triangle should be drawn as large as is convenient. Then s and t are measured in actual inches. In order to obtain feet per second, t must be given in seconds and s in feet. A scale must be established for s, giving the feet relationship to one inch. Likewise, such a scale must be established for t, giving the second relationship to one inch. The quotient of s scale over t scale gives the scale factor. In the example in Figure 3 the scale factor is 50 and the velocity V is 30.2 feet per second.



STEEL STRAIGHT EDGE having a polished mirror surface is all that is needed to erect a normal line accurately at point P. **(FIGURE 2)**



SLOPE TRIANGLE, drawn large for convenience, is completed with its hypothenuse tangent to the displacement curve at point P. **(FIGURE 3)**



ACCELERATION REPRESENTS the rate of change of speed. The slope triangle for point P on the speed curve has been erected. **(FIGURE 4)**

On a given displacement curve, a sufficient number of points are thus evaluated so that the desired portion of the velocity curve can be plotted. It is obvious that in regions of rapid changes in curvature, a greater number of points must be taken than in those of more gradual change. When extremely high rates of change of curvature are encountered, they may be enlarged photographically or by other means so that they may be processed more accurately.

Having thus developed the necessary portion of the velocity curve, the points for a corresponding acceleration curve may be found as shown in Figure 4. The procedure is analogous to that in Figure 3. The tangent drawn at point P furnishes the hypothenuse in the triangle $\Delta V\ \Delta t$ as adjacent sides. The quotient of the inch-velocity relation over the inch-time relation gives the scale factor (250 in this example). Now $\frac{\Delta V}{\Delta t} \times$ scale factor gives the acceleration at point P, which is 175 feet per second² in this case. Processing a number of points of the velocity curve — more in the salient portion and less in the one of more gradual curvature — a sufficient number of curve points are obtained to thus draw an acceleration curve.

Method is naturally accurate

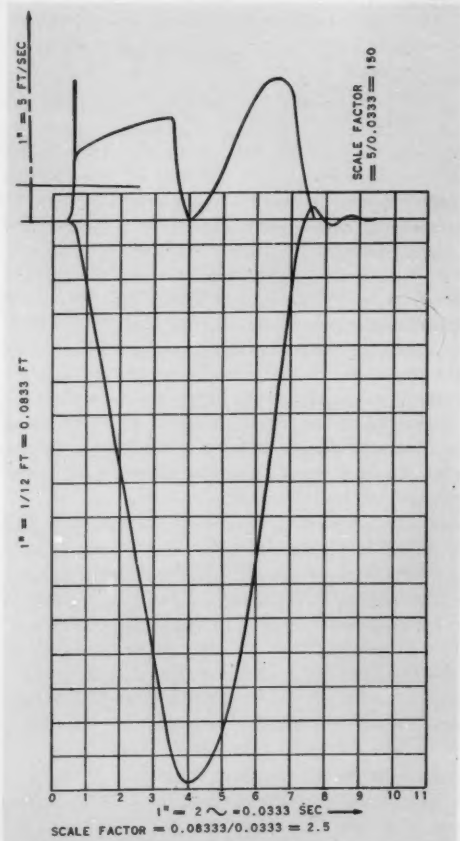
The inherent accuracy of the surface mirror method of graphical analysis results from three simple physical facts. First is the inherent accuracy of the "line-of-sight" of the human eye. The second is the fact that using the mirror the eye sees a curve which is symmetrical about point P and, therefore, has a much simpler curvature to view. Finally, the use of the mirror results in a doubling magnification of any error as perfect alignment of the mirror straight edge is approached. However, ordinary glass mirrors, having their reflecting surface on the rear, cannot be used because of the parallax effect in the thickness of the glass.

In a check on the accuracy of the method described, the displacement curve of a simple harmonic motion characteristic of the acceleration of the contacts in a power circuit breaker was drawn and processed graphically. The equation of the harmonic motion being available, the mathematical differentiation was also carried out and the results of the two methods compared. The maximum error at any single point in the first graphical differentiation was 2.84 percent and the average error was 0.39 percent. The maximum cumulative error at any single point through two graphical differentiations was 1.35 percent and the average error was .43 percent.

This graphical method of differentiation is, of course, most useful where no mathematical formula is available, as in the case of most circuit breaker analyzer or speedgraph displacement curves. In fact, it is believed to be the only simple graphical method affording sufficient accuracy for general use.

A common application is the graphical differentiation of a typical speedgraph curve of a high-speed power circuit breaker.

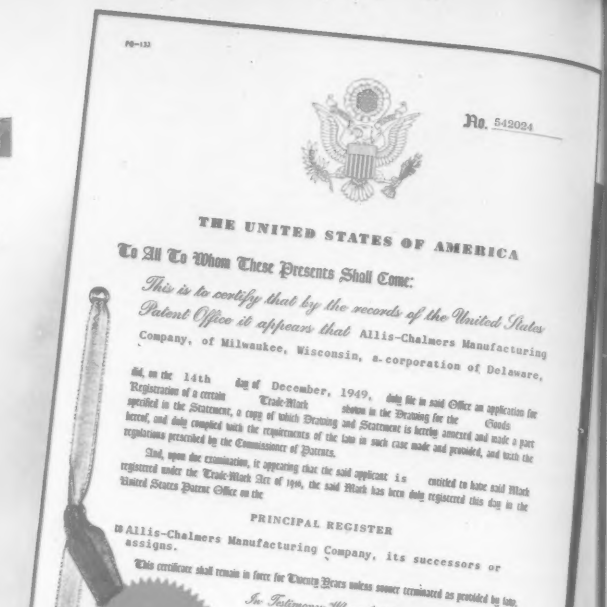
An enlargement of the critical end points of the reclosure curve was avoided to demonstrate that sufficiently accurate results may be obtained by the careful selection of curve points. Figure 5 shows the curve as it was taken by the speedgraph. A number of curve points were differentiated and the resulting velocity curve was drawn at the top of the displacement curve, using the time abscissa of the original curve. A maximum velocity of 25 feet per second was measured. The second graphical differentiation was carried out for the maximum slope of the curve and a value of 1170 feet per second² found, but the acceleration curve was not drawn to avoid unnecessary complication. In most cases the drawing of the acceleration curve can be dispensed with as the values for the acceleration are found from the velocity curve. Furthermore, the velocity curve shows clearly the maximum slope and usually it is sufficient to find the acceleration at that particular point only for the force evaluation.



HIGH DISPLACEMENT CURVE of contacts of a high-speed reclosing circuit breaker has corresponding velocity curve plotted above it. Points were derived by graphical differentiation. **(FIG. 5)**

PROTECT
Your Trademark

by ERWIN KOPPEL
Attorney, Patent Dept.
Allis-Chalmers Mfg. Co.



PO-132

No. 542024

THE UNITED STATES OF AMERICA

To All To Whom These Presents Shall Come:

This is to certify that by the records of the United States Patent Office it appears that Allis-Chalmers Manufacturing Company, of Milwaukee, Wisconsin, a corporation of Delaware, did, on the 14th day of December, 1949, duly file in said Office an application for Registration of a certain Trade-Mark shown in the Drawing for the Goods specified in the Statement, a copy of which Drawing and Statement is hereby annexed and made a part hereof, and duly complied with the requirements of the law in such case made and provided, and that the regulations prescribed by the Commissioner of Patents.

And, upon due examination, it appearing that the said applicant is entitled to have said Mark registered under the Trade-Mark Act of 1946, the said Mark has been duly registered this day in the United States Patent Office on the

PRINCIPAL REGISTER

to Allis-Chalmers Manufacturing Company, its successors or assigns.

This certificate shall remain in force for Twenty Years unless sooner terminated as provided by law.

In Testimony Whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this eighth day of May , in the year of our Lord one thousand nine hundred and fifty-one and of the independence of the United States the one hundred and seventy-fifth.

John A. Marzall
COMMISSIONER OF PATENTS

ATTEST:
S. Wm. Gilman
LAW EXAMINER

Your trademark is what you make of it . . . so protect it by taking proper action.

TRADEMARKS are one of the oldest of human institutions. Whenever the remains of early civilization are found, in Egypt, Crete, Greece, or Rome, dating as far back as 4,000 years, wares turn up imprinted with the name or mark of some primitive trader.

The idler, scrawling his name upon the walls of Rome or Pompeii, made his mark echo through the corridors of time, but it was the kings who pressed their names and titles on the bricks of Babylon that truly approached the use of a trademark as an indication of origin for the marked goods. Much of the early use of trademarks served as a general identification for the goods, for most people at that time could not read.

The philosophy behind much of the early use of trademarks was merely to facilitate identification of goods. Egyptian law required the owner of every brickyard to place his name on the bricks he sold, and also the name of the slave who actually made the bricks, so that responsibility for defective bricks could be fixed. Today, the trademark not only identifies the origin of goods but also helps to promote and advertise them and serves as a guaranty of satisfactory quality.

Use of the trademark as a guaranty of satisfaction originated during the Middle Ages when the mark of the guild, accompanied by the mark of the individual craftsman, originally was utilized to identify slovenly work as well as to show that the article was made by a member of the guild. For example, the law of the armorers required each member of the guild to mark his product. The reason was clear enough, for a fighting man staked his life on the weapons he bore and the armor he wore, and if anything went wrong his widow or next of kin wanted to find the varlet who was responsible.

In time, the marks appearing on some craftsman's work, which was better than others, came to connote better workmanship and thus symbolize the good will which is the essence of the modern trademark. The passage of time saw the passing of the guilds, but marks of this nature survived and with them the modern idea of trademarks symbolizing a satisfactory reputation and bearing an asset value.

It is easily seen how this guaranty function of a trademark could work in reverse. If you were to produce an inferior product, your trademark would become a mark of unsatisfactory quality which the public would soon learn to avoid. Under such adverse circumstances your business would probably be short-lived and your trademark abandoned.

Federal laws provide uniform coverage

Starting with the independence of our country, the need for a Federal trademark law grew as the commerce in our nation expanded. Although each state provides protection when your mark is used within its jurisdiction, the protection varies according to the particular laws of each state. On the other hand, a Federal statute provides a uniform law when your trademark is used in several states, and accordingly in 1870 Congress passed the first Trademark Act. Subsequent Acts in 1881, 1905, and 1920 corrected deficiencies in the early law. Since 1920 Congress has again realized that further changes were necessary in the Federal Law, and the most recently revised Trademark Law became effective in 1947. This law modernizes the older statutes to conform with the trend of recent court decisions which have granted to you as a trademark owner protection commensurate with legitimate present-day business practice.

To understand the full meaning and impact of the present Federal Trademark Act, it must be understood that your trademark rights do not depend upon registration in the United

States Patent Office. Exclusive rights to a mark are acquired when you use your mark on products in commerce. This use must continue if your rights are to continue.

Federal registration of a trademark adds certain benefits to the rights already acquired by use. A registration facilitates the enforcement of your rights, furnishes a public record of trademarks and enables your mark to be protected under a uniform public law throughout the states.

The present Trademark Act, commonly taking its name as the Lanham Act from its sponsor, Congressman Fritz Lanham, has incorporated a number of modernizing benefits designed to induce you to register your trademark. These benefits automatically accrue to your mark upon registration, and at the same time the nation benefits by the compiling of a public record for searching.

Adoption of your trademark

Suppose you decide to adopt a new trademark, and you desire to use it on electric motors. The first step is to have a search made of trademarks currently in use, both registered and unregistered. If the search is competent and reveals no confusingly similar mark, you can feel reasonably free of infringement liability in adopting your new trademark. For example, the search may disclose the same mark used on paper napkins or jewelry, but these uses on different products would not present a confusing picture to the public alongside of your use on electric motors. It is obvious that under such circumstances the law will allow the same trademark to be used by different parties.

Adoption of a trademark consists in applying the mark in a distinctive manner to the products. You may cast it in the casing of your motor, apply it by means of a decalcomania, or affix the mark to the product in any number of ways. If the product is too small to bear the mark, it may be applied to the container. A provision of the Lanham Act expands this general rule by allowing trademark use in displays or in connection with services, but the display must be associated with the product and the product sold or transported in commerce. To acquire the protection of the Federal Law this commerce must be between the several states or between the United States and foreign countries.

As soon as your use commences, your trademark rights are established and an application for registration in the United States Patent Office can be made. The application must be in a prescribed form, accompanied by specimens or facsimiles of the mark, a drawing of the mark and a $25.00 fee. Your application will be examined by the Patent Office, and if the mark is found to be entitled to registration, a certificate of registration will be issued.

Benefits of the Lanham Act

A Lanham Act registration entitles your trademark to the greatest protection ever available under Federal law. As in the older law the registration is evidence of your exclusive right to the mark, and the additional new benefits hereinafter discussed show the increased protection available with a Lanham Act registration.

Constructive notice extends coverage

The registration of your mark is now constructive notice of your claim of ownership. Formerly when another party used a mark that infringed on your rights, it was necessary to give actual notice of the infringement before damages could be recovered. Constructive notice means that, once your mark is registered under the Lanham Act, everyone is charged with having knowledge of this registration, and no adverse claim or trademark rights may be asserted by another if he has adopted and used a confusing mark after your registration was granted. This means that adoption and use of a confusingly similar mark by another after your mark is registered is an unlawful use and cannot be justified by a claim of innocence, good faith or lack of knowledge. The practical effect of this constructive notice is to give your registration a nationwide coverage.

Prospective users of trademarks, who wish to avoid the liability which constructive notice may present, now have the duty of searching the Patent Office register before adopting and using a mark. This practice is commonly followed; and if you are considering the adoption of a new mark, it is strongly advised to have such a search made to help avoid a costly infringement action.

Concurrent registration available

Until the Lanham Act was passed, only the owner who first used the trademark could obtain a registration. This created a hardship where the same or a similar mark was adopted in different areas, and use on similar goods was continuing concurrently without any confusion to the public.

The Lanham Act now provides for registration of the same or similar marks to more than one owner, although each is using the trademark on similar goods but without confusion to the public.

Suppose that you intend to use your new trademark on electric motors. It may be that at the same time another party has also started to use this mark for electric motors but in a different area. It may well be that upon presentation of these facts which show no confusion to the public, the Patent Office will grant a registration to each of you for the same mark.

An example of a concurrent registration is shown in Figure 1 where the trademark "WEDJIT" was registered to differ-

Ser. No. 528,091. UNITED-CARR FASTENER CORPORATION, Cambridge, Mass. Filed July 7, 1947. CONCURRENT USE for the area comprising the whole of the United States and its Territories except the States of California, Oregon, and Washington.

WEDJIT

FOR METALLIC PLATE AND STUD FASTENER FOR ATTACHMENT TO FLOORS, WALLS, AND THE LIKE, AND FOR USE IN ANCHORING EQUIPMENT, ELEMENTS OF CARGO AND THE LIKE, THERETO.
Claims use since Oct. 31, 1946.

WEDJIT is registered as a trademark by the Adams Rite Manufacturing Co. and United-Carr Fastener Corporation, but in different areas. **(FIGURE 1)**

Ser No. 528,092 ADAMS RITE MANUFACTURING COMPANY, Glendale, Calif Filed July 7, 1947. CONCURRENT USE for the area comprising the States of California, Oregon, and Washington

WEDJIT

FOR METALLIC PLATE AND STUD FASTENER FOR ATTACHMENT TO FLOORS, WALLS, AND THE LIKE, AND FOR USE IN ANCHORING EQUIPMENT, ELEMENTS OF CARGO AND THE LIKE, THERETO.
Claims use since Dec 18, 1945.

ent owners for the same product with the limitation that each owner will pursue his business in a different area.

The same trademark may also be registered to different owners when it is used on different products.

Secondary meaning protection

The courts which enforce the exclusive rights of the trademark owner have long recognized that a trademark which originally is not sufficiently distinctive to have exclusive rights may by long and widespread continuous use acquire secondary meaning rights which will be accorded full protection.

Secondary meaning may attach to any common word in the English language which by long use becomes identified with the product of a certain owner. A judge put it this way when explaining why the word "standard" was entitled to exclusive trademark rights under certain circumstances:

> ". . . If plaintiff by more than thirty years' use of the word 'STANDARD' has caused this word to be lifted from the public domain and to be applied and understood in the oil business as designating its business, and its gasoline, then no one has the right to use this word in no wise as to cause confusion among customers."

Formerly, a registration would be refused if the mark in use was geographical, descriptive or a surname. It is easily seen why registration of such a mark, newly conceived, is refused, for no person should have the right to preempt such names or words from the language when others may bear the name or wish to use it in a descriptive or geographical sense.

If, however, such a mark is used over a sufficiently long period of time to distinguish and identify the origin of certain products, this mark may acquire a secondary meaning, other than its ordinary meaning, become distinctive as applied to such products and consequently be entitled to protection. Such marks as "WALTHAM," "KITCHEN KLENZER" or "FORD," which illustrate a geographical mark, a descriptive mark and a surname, have established this secondary meaning.

The Lanham Act has incorporated this secondary meaning doctrine in its provisions. The proof of distinctiveness is a question of fact in each case, but the Patent Office may accept this proof by an affidavit from the owner alleging five years of substantially exclusive use just prior to filing the application. However, the Patent Office may require further proof of distinctiveness in the case of certain marks. In such case the owner may obtain affidavits from dealers and customers to the effect that the mark is distinctive of the owner's products.

Descriptive marks still vulnerable

If you are considering the adoption of a mark of this nature, give it another thought. The validity of a registration of this type of mark is vulnerable in litigation to an attack on the grounds that the mark lacks trademark significance, and in the case of a descriptive mark you may not even be successful in attempting to wrest the word from the public domain. Far better to adopt an arbitrary coined word or expression, such as was done in the case of "KODAK" for cameras. "KODAK" had no meaning or value when it was adopted as a trademark, but by promotion of the mark and the sale of a fine product it has come to indicate the origin of that camera. A campaign for the promotion of a trademark is similar for all types of marks, irrespective of their nature, and that is why it is recommended that an arbitrary coined mark be adopted in the first instance.

If you already are using a mark that is descriptive, geographical or a surname, steps should be taken as soon as the mark becomes distinctive to obtain a registration, for a registration held five years attains an incontestable status. The advantages of this status will be discussed later in this article.

Ser. No. 545,417. ALLIS-CHALMERS MANUFACTURING COMPANY, Milwaukee, Wis. Filed Dec. 26, 1947. (Sec. 2f.)

ALLIS - CHALMERS

FOR AGRICULTURAL MACHINERY AND IMPLEMENTS FOR SOIL TILLAGE, PLANTING, HARVESTING AND FERTILIZING; MACHINERY FOR MATERIAL COMMINUTING, MATERIAL PACKING, MECHANICAL POWER TRANSMISSION, FLUID PUMPING, GAS COMPRESSING, MECHANICAL SIZE GRADING; MECHANICAL SEPARATORS, MATERIAL CONVEYERS; MACHINERY AND IMPLEMENTS FOR WOOD PROCESSING; POWER TURBINES, MECHANICAL AGITATORS, INTERNAL COMBUSTION POWER APPARATUS, MECHANICAL SAMPLERS, SOLVENT EXTRACTION APPARATUS, KILN BORING APPARATUS; AND PARTS THEREOF.

Claims use since Nov. 1, 1903.

SURNAMES THAT HAVE acquired secondary meaning may obtain full registration benefits. This trademark has been registered because its five years of substantially exclusive use constitutes evidence of trademark rights acquired by secondary meaning distinctiveness. **(FIGURE 2)**

The surname "ALLIS-CHALMERS," shown in Figure 2, has been registered in Class 23 in this manner. Note in Figure 2 the reference to Section 2(f). This is the section of the Lanham Act granting registration to marks acquiring secondary meaning.

Test for conflicting marks changed

Until the Lanham Act set up a new test as to whether the same or similar marks conflicted, the Patent Office would deny registration to a conflicting mark by applying the nebulous and uncertain statutory test of "merchandise of the same descriptive properties."

The Patent Office has various classifications of goods for the convenience of registration, and these classes had formerly been used as a guide in determining whether the marks conflicted. For example, Class 21 is the Electrical Class which covers both electric motors and flashlights. If another party had registered a mark for flashlights similar or the same as yours, the Patent Office under the old law might refuse to register your mark for motors. In actual practice there probably would be no confusion created by the concurrent use of both marks, yet despite your established trademark rights you might have been denied registration.

The Lanham Act rectifies this situation by stating that the Patent Office classification is not to be used as a basis for accepting or denying a registration, but is to be maintained primarily for the convenience of Patent Office administration. The Lanham Act then sets the present test for conflicting marks as to whether or not the mark for which registration is sought is likely to cause confusion or deceive purchasers as to origin of products, irrespective of the classification or descriptive properties of the goods or services involved.

Using the new test of likelihood of confusion rather than classification, it would also be possible for the Patent Office to deny a registration although the conflicting marks are in different classes. The Patent Office might cite the trademark "TEXROPE," registered in Class 23 by Allis-Chalmers Manufacturing Company for power transmission equipment and belts, to deny registration of the same mark to another for goods, such as electric switches in Class 21, if it were felt that a likelihood of confusion was presented to the public.

Incontestability protects owner

The validity of a registered trademark formerly could be challenged throughout the life of the registration. This situation could be very costly to a businessman who had spent a great deal of money and time building up good will in a mark.

An example illustrates the inequity of this condition. Procter and Gamble had spent many thousands of dollars over a period of fifteen years promoting the mark "CHIPSO," when litigation was started with a company using "CHASE-O." The other company succeeded in having the "CHIPSO" registration canceled in the Patent Office on the grounds of likelihood of confusion, despite the fifteen years concurrent use of both marks and despite the decision in a corresponding court action that the other company could not stop the actual use of "CHIPSO."

The Lanham Act now offers security to the registrant in that five years after the date of registration a mark may become "incontestable." This means that anyone who wishes to cancel a registration on one of the statutory grounds of nonregistrability must act within five years of the registration grant.

As mentioned before, this incontestable status is highly advantageous if you have a mark that is a surname or has a descriptive or geographical nature. Once you have attained this incontestable status, an attack on the validity of the registration for these reasons cannot be made. And justly so, as shown by the inequity of the "CHIPSO" case, for when your trademark has an established meaning, and has been promoted over a period of five years, it is entitled to such protection.

Actually the word "incontestable" is not the best choice, for under certain conditions specified in the Lanham Act a registration can always be canceled. If it is shown that a mark has been abandoned or has become the common name of the article on which a patent has expired, is being used by an assignee to misrepresent the origin of products or if the registration was obtained through fraud, the registration may be canceled at any time. However, as to other grounds of cancellation the registration is secure once the incontestable status is attained.

Service marks are registrable

The need for modernizing the former Trademark Act was keenly felt in the field of service marks. These are marks used in the sale of advertising of services to identify and distinguish them from the services of another. These may include symbols, slogans, distinctive features of radio and certain other designations which were not registrable until the passage of the Lanham Act.

To illustrate the function of a service mark, let us imagine that, instead of using your trademark in the sale of electric motors, you use your mark in the business of servicing electric motors. Assume your business extends to several states, so your mark is protected by the Federal law. Since you are now selling a service, your trademark will not appear on any product. Yet promotion of your service mark will cause it to acquire the same distinctiveness as to source of origin as any mark affixed to a product.

However, to obtain registration under the former Trademark Act the mark had to be affixed to the goods. As in the case of servicing motors, the affixation of trademarks to the goods is not possible in the case of transportation companies, laundries, banks, insurance companies and the like, so the rights acquired in their trademarks by these owners were formerly denied registration.

Ser. No. 560,198. EDW. F. GARDNER, Los Angeles, Calif. Filed June 25, 1948. SERVICE MARK.

Duffy's Tavern

FOR ADVERTISING AND ENTERTAINMENT SERVICES IN THE NATURE OF A RADIO PROGRAM. Claims use since Mar. 1, 1941.

TRADEMARKS USED to designate the origin of a service, such as *Duffy's Tavern* for a radio program, may now receive the same registration benefits of the Lanham Act accorded to the usual type of trademark, such as *Kodak* or *Coca-Cola*. **(FIGURE 3)**

Ser. No. 541,873. NATIONAL BROADCASTING COMPANY, INC., New York, N. Y. Filed Nov. 20, 1947.

THE MARK COMPRISES THE MUSICAL NOTES G, E, C PLAYED ON CHIMES.

FOR BROADCASTING OF RADIO PROGRAMS. Claims use since November 1927.

A SOUND MARK, which has established trademark distinctiveness, may be registered under the present Trademark Act. The first sound mark registered was the NBC chimes. **(FIGURE 4)**

The Lanham Act now provides all the benefits of registration for a service mark when the mark is distinctive of an applicant's product, and a great number have been registered since the Lanham Act became effective in 1947. Recent registrations of service marks include marks such as the radio program "Duffy's Tavern," shown in Figure 3, and the first sound mark, the NBC chimes, shown in Figure 4.

Miscellaneous provisions extend protection

Trademarks entitled to all the benefits of the Lanham Act are registered on the Principal Register. The Lanham Act also provides a Supplemental Register to register those marks which are capable of distinguishing an owner's goods or services, but which do not fulfill the requirements for registration on the Principal Register. For example, a mark may be descriptive, geographical or a surname, but having been used less than five years or being unable otherwise to prove distinctiveness, the mark is incapable of registration on the Principal Register.

Marks registered on the Supplemental Register are not entitled to the aforementioned benefits of the Lanham Act, but this type of registration may be helpful to the owner engaged in exporting to foreign countries. In many foreign countries registration is essential to protect the owner's rights, and a number of these countries require a certificate of registration from the home country before the foreign certificate will be issued. Thus, although the owner may not be able to obtain registration on the Principal Register, he may yet acquire a certificate of registration on the Supplemental Register which will enable him to obtain a foreign registration. An example of the type of distinctive mark registered on the Supplemental Register is shown in Figure 5 where the container for the goods, "No. 5 Chanel," is registered.

Another provision of the Lanham Act requires you to file an affidavit during the sixth year following the date of your registration showing that the mark is still in use. If the affidavit of use is not filed after your trademark for electric motors is registered six years, your registration will be canceled

by the Patent Office. This will eliminate the "dead wood" from the Patent Office records and result in up-to-date records for searching.

A number of other benefits appear in the new Act, but they will not be discussed at this time. It is apparent that sufficient benefits have been made available to the trademark owner, for the volume of applications in the Patent Office has substantially increased since the passage of the Lanham Act.

Proper trademark use

The foregoing analysis of the Lanham Act shows the extent to which Congress has gone to grant additional protection for your trademark rights. However, registration alone will not guarantee complete protection for your mark. As pointed out at the beginning of this article, trademark rights depend on use, and such use should be in accord with certain recommended principles to help preserve the exclusive rights to your mark.

Valuable trademark rights can be lost if improper practices are observed. This misfortune occurred to such well known trademarks as "ASPIRIN" and "CELLOPHANE," and more recently to "ESCALATOR."

The following principles of recommended trademark usage are set forth as a guide for use in correspondence, advertising, and other literature.

1. A trademark should be set off distinctively from the surrounding context. This can be done by the use of a different type, color, italics, capital letters, quotation marks or any other means that will result in the trademark being set off distinctively.

2. The trademark should not be used as a generic term; that is, as the name of the article itself. Trademarks should properly appear in an adjective sense, as in "TEXROPE belts," "COMPTOMETER calculating machine" or "RUPT-AIR circuit breakers."

3. A trademark designating a specific product should not be preceded by the company name. The danger of using such a phrase as "Allis-Chalmers MAGNAFLO feeder" is that "MAGNAFLO" may become known as a generic type designation rather than an indication of origin, and as such the trademark would become available for use by anyone making that product. To indicate origin of the product a phrase such as "MAGNAFLO feeder, a product of Allis-Chalmers," or "MAGNAFLO is an Allis-Chalmers trademark," may be used.

4. Trademarks should not be mutilated or corrupted in any manner. A symbol mark, such as the Diamond and Seal shown in Figure 6, should always appear exactly in the prescribed form. Hyphenated trademarks, such as "ALLIS-CHALMERS," should always be reproduced with the hyphen. Corruption by pluralizing, such as in "TEXROPES," rather than "TEXROPE belts," is to be avoided.

Your trademark is what you make it. Conscientious promotion may make your mark a valuable asset, but before your promotional campaign continues, examine your present trademark program along these lines:

1. Are you using your trademark in such a manner that the law extends its protection?

2. If your trademark is registrable, are you seeking registration under the Lanham Act?

3. Are you using your trademark properly so as to preserve your exclusive rights?

511,105. (CLASS 6. CHEMICALS, MEDICINES, AND PHARMACEUTICAL PREPARATIONS.) CHANEL, Inc., New York, N. Y. Original filed Nov 1, 1947 application filed complete June 10, 1948. Serial No. 539,852.

The trade-mark consists of a rectangular label on which the notations "No. 5" and "Chanel" are displayed, said label being affixed to a bottle with a glass stopper of the design shown in the drawing, a seal being fastened to the neck of said bottle by cord. Applicant claims ownership of Registrations Nos. 195,366, 215,556, 237,407 and 422,339.

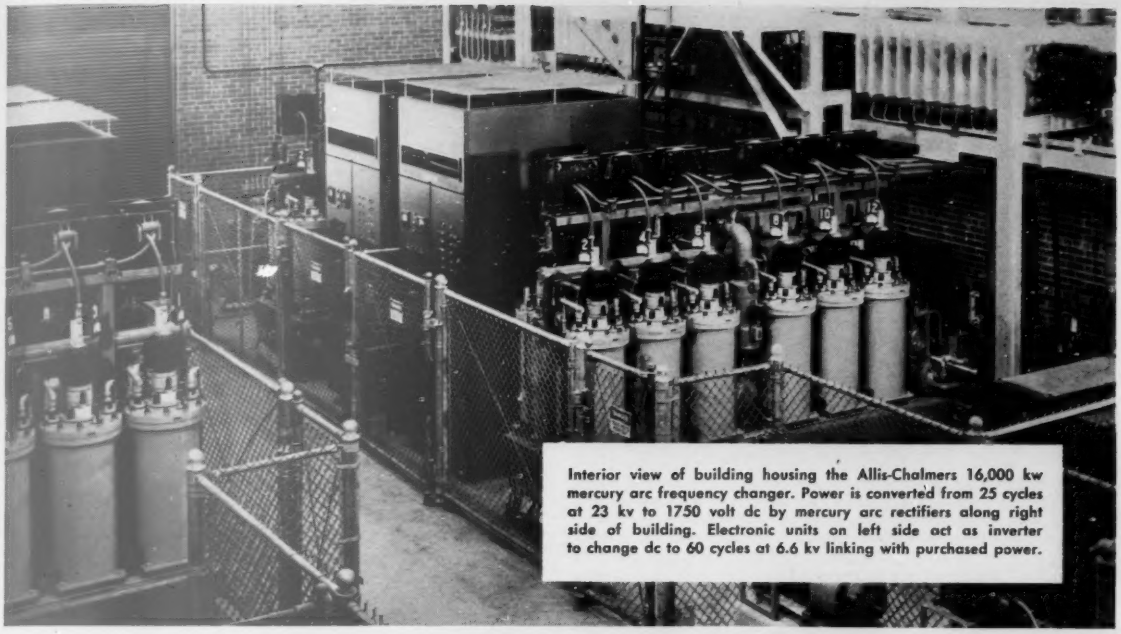
FOR PERFUME.
Claims use since 1924.

TRADEMARKS THAT DO NOT meet requirements of the Principal Register may be registered on the Supplemental Register. Distinctive containers and labels, such as *No. 5 Chanel,* may be registered on the Supplemental Register as a basis for foreign registration. **(FIGURE 5)**

DIAMOND AND SEAL trademark of Allis-Chalmers Mfg. Co. is a symbol mark. To preserve exclusive rights, such symbol marks should always appear exactly in their prescribed form. **(FIGURE 6)**

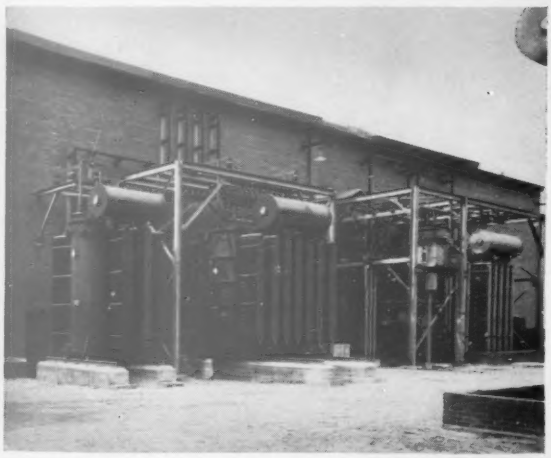
TRADEMARK *RUPTAIR* should be used in an adjective sense to preserve its distinctiveness. Properly used to identify product, *Ruptair* circuit breaker, it retains full protection provided by the Lanham Act.

***TEXROPE* BELTS,** not *Texropes,* is the proper way to designate these particular transmission belts. Failure to follow recommended principles could endanger and lose trademark protection.



Interior view of building housing the Allis-Chalmers 16,000 kw mercury arc frequency changer. Power is converted from 25 cycles at 23 kv to 1750 volt dc by mercury arc rectifiers along right side of building. Electronic units on left side act as inverter to change dc to 60 cycles at 6.6 kv linking with purchased power.

1st Mercury Pool Frequency Changer on Duty at Gary



Allis-Chalmers rectifier transformers, reactors and oil circuit breakers serve the mercury arc frequency changer. Outdoor equipment on 60 cycle side, from left to right: dc reactor, 8000 kw self-cooled transformer, 15 kv, 500,000 kva i.c. oil circuit breaker, and 8000 kw self-cooled transformer.

AMERICA'S FIRST commercial mercury pool type frequency changer is located at the Gary Sheet and Tin Mill of the United States Steel Company.

Allis-Chalmers was selected to build this "first of its kind" largely because of wide experience in manufacturing and applying mercury arc rectifiers. Other Allis-Chalmers rectifiers are on duty here providing power for the 250 volt dc mill supply system.

Now successfully completing its eighth year of operation, the 16,000 kw electronic frequency changer interchanges power between the 25 cycle system and the 60 cycle purchased power system. *Regulex* rotating exciter sets automatically control unit operation.

The 25 cycle power is largely generated by Allis-Chalmers steam turbines and gas engines from by-product fuels and waste heat at the nearby Gary Steel Works and South Works. The frequency changer greatly increases the flexibility and economy of United States Steel operations in the Gary area by permitting full utilization of by-product power and reducing purchased power demand peaks.

Whatever your electrical needs, A-C will supply you with dependable, quality equipment. For information on the *complete* range of equipment, call your nearest A-C office. Allis-Chalmers, Milwaukee 1, Wisconsin.

A-3507

Regulex and *Ruptair* are Allis-Chalmers trademarks.

ALLIS-CHALMERS

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Power, Electrical, Processing Equipment for Iron and Steel

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CONTROL
M. O. ANNEX

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All this adds up to simplifying and speeding the job by calling on Allis-Chalmers. Check the following pages for a listing of some of the Allis-Chalmers lines that may be useful to you. Allis-Chalmers, Milwaukee 1, Wisconsin. A-3442

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